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Foot-rot in Sheep: A Preliminary Note on the Probable Causal Agent.

*By W. I. B. Beveridge, B.V.Sc.**

In an earlier paper (this *Journal* 8: 308, 1935), the writer described experiments which showed that the belief, which is rather widely held, that *Fusiformis necrophorus* is the cause of foot-rot, is probably erroneous. At the time it was thought that an organism seen constantly in lesions was probably the causal agent, but when this organism, *Spirochaeta penortha,* was isolated, the disease could not be produced with cultures of it.

Foot-rot has been produced in 105 out of 107 feet which have been subjected to scarification between the digits followed by the application of infected tissue, necrotic material, and pus obtained from lesions of foot-rot. The infective material will subsequently be referred to as material from foot-rot lesions. Of 121 feet which were scarified and to which cultures of *F. necrophorus* were applied, none developed foot-rot. Similarly, 54 feet were treated with cultures of *Sp. penortha* without any developing foot-rot. Broth suspensions were made of material from foot-rot lesions, and some were filtered through Berkfeld and Gradocol filters, and others were centrifuged. The filtrates and supernatant fluids were non-infective when tested alone or with *F. necrophorus* and *Sp. penortha* on fifteen feet. Thus no evidence has been obtained that a filtrable virus is the causal agent of foot-rot.

Examination of smears, carefully prepared from the junction of the healthy and diseased tissue in foot-rot cases, showed, in the majority of instances, a preponderance of two organisms, one being *Sp. penortha* and the other a Gram-negative bacillus closely resembling *F. necrophorus.* It was found that the latter was not, as at first thought, *F. necrophorus,* for it was motile, whereas *F. necrophorus* is not. The Gram-negative bacillus, which probably belongs to the genus *Fusiformis* and will be referred to as the fusiform of foot-rot, was isolated in culture. Briefly, it is a rather slender, Gram-negative, non-sporing anaerobe which usually grows as a thin spreading film on blood agar plates. Cultures of this organism also failed to produce foot-rot in any of 37 feet to which they were applied, sometimes together with *Sp. penortha* and sometimes passaged a number of times through the feet of sheep.

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Various other organisms, both anaerobes and aerobes, were isolated from lesions of foot-rot, but the disease could not be produced with cultures of these. A virus-like organism, cultivable on blood agar and probably belonging to the group described by Laidlaw and Elford (Royal Soc. London, Proceedings 120B, 292), was isolated from a number of foot-rot cases but was non-infective.

A search was made for protozoa and *Rickettsia* in smears and sections, but neither was found. Sections usually showed an organism morphologically similar to the fusiform, and sometimes the spirochaete, penetrating ahead of other bacteria.

At this stage of the investigation, it appeared that foot-rot, which behaved as a typical, specific, contagious disease and could be readily produced with material from lesions, was caused by some organism which was large enough to be deposited by ordinary centrifuging (5,000 r.p.m.) but which was either not readily cultivable on ordinary media or else lost virulence in a few days under the conditions of artificial cultivation employed.

Employing a different method of attack, whole mixed plate cultures of foot-rot material, grown on V.F. blood-agar, in an anaerobic atmosphere with various percentages of CO_2 added, were tested after five days' incubation. Five such cultures proved non-infective. A special medium which, among other constituents, contained 25 per cent. serum, was prepared. Two out of nine cultures on this medium proved infective. There had been seen in smears from lesions an organism which had not been cultivated but to which little attention had been paid, since it was usually present in comparatively small numbers. This organism was found growing in some cultures on the special serum-enriched medium but not on V.F. blood-agar. The organism was isolated and applied to scarified sheep's feet, together with the spirochaete and the fusiform, and typical foot-rot was set up.

This organism is a Gram-negative, non-sporing anaerobe which grows on V.F. media to which 25 per cent. serum has been added, but only very poorly on 5 per cent. blood-V.F.-agar. In smears from lesions, in which it is usually present in comparatively small numbers, it takes the form of rods, from 3 to 10μ long and from 0.8 to 1.2μ wide, having enlarged, knob-like ends. In cultures, it is somewhat smaller and the knobs are less pronounced or absent. It grows, though not vigorously, in V.F.-cooked heart medium in which it produces blackening and later partial digestion of the meat particles. On 25 per cent. serum-V.F.-agar, incubated in an anaerobic atmosphere with 5 per cent. or more of CO_2, it forms colonies which are etched into the surface of the medium, giving them a very characteristic sunken appearance. For the sake of convenience, this organism, which probably belongs to the genus *Bacteroides*, will be referred to as "organism K" until a suitable classification has been definitely decided upon.

Typical foot-rot has been produced in sixteen feet on adult Merino sheep to which organism K has been applied, together with *Sp. penortha* or with *Sp. penortha* and the fusiform. Organism K alone or with only the fusiform has produced lesions which might be diagnosed as mild foot-rot, but they were less severe than those of the typical disease.

Only a limited number of experiments with this organism have so far been carried out, and further investigation is planned to determine definitely the role of the spirochaete and the fusiform. The experiments conducted to date suggest that the fusiform is probably commonly present in the environment, possibly in the faeces, as organisms morphologically similar to it have appeared in all of six tests in which only organism K, or organism K and the spirochaete, were applied. In accordance with this view is the fact that lesions produced by application of organism K and the fusiform were no more severe than those produced by organism K alone. On the other hand, the spirochaete has only appeared in three out of six tests in which organism K, or organism K and the fusiform, were applied, and its appearance in these cases may possibly have been due to accidental contamination from other experimental sheep kept nearby.

Investigations to date suggest that organism K is the primary causal agent of foot-rot and that *Sp. penortha* is perhaps also necessary for the development of the typical disease. Although the fusiform may also play a part, it is perhaps a secondary invader commonly present in the environment.

Investigations on the Viability of the Contagium of Foot-rot in Sheep.

*By W. I. B. Beveridge, B.V.Sc.**

Summary.

1. In material from lesions of foot-rot, kept moist or air-dried, the infective agent survived 24 hours but not four to eight days. When material from lesions was mixed with mud, the infective agent usually survived three days, rarely one week, and never three weeks. In sheep faeces it survived one week on one of two tests, but not two weeks.

2. In a muddy yard infected by placing infected sheep in it, the infective agent was demonstrated to have survived 24 hours in one out of three experiments. In six experiments the infection could not be demonstrated in damp pasture from which infected sheep had been removed from nine hours to two weeks previously.

3. The infective agent can survive at least three and a half years in lesions on chronically infected sheep. Apparently-recovered sheep may occasionally harbour the infection for seven months in superficial skin lesions between the digits, for at least a week in hidden foci of infection under the horn, and for one week without showing any lesions. On the other hand, sheep recovered for a month or more and showing no lesions are apparently free of the infection. The infection probably cannot survive in skin lesions on sheep elsewhere than on the feet.

1. Experiments on the Viability of the Infective Agent apart from the Sheep.

In the experiments about to be described, the source of the infective agent was material obtained by scraping infected tissue and necrotic material from lesions of foot-rot. This material when fresh has, in over 40 experiments, always proved capable of producing foot-rot when applied to sheep's feet after scarification between the digits, almost 100 per cent. of feet becoming infected. Adult Merino sheep were used in all experiments, and we have never encountered an insusceptible sheep. The causal organism of the disease had not been discovered when these experiments were carried out, but in any case it is preferable to work with natural infective material, for here the infective agent is present in the form and in the medium in which it is present under field conditions. The method of detecting its presence in mixed material by application to sheep also has advantages over cultural tests, as it imitates what takes place in the field.

All sheep on which tests were being carried out were isolated from infected animals and from other test animals. Strains of foot-rot from four different districts have been used but no difference has been observed between the strains. In most of the experiments, each test for viability consisted of applying the material to two feet on the same sheep.

(i) *Viability of Infective Agent in Material from Lesions.*

The results of these experiments are summarized in Table 1. Experiment Ia comprises four separate tests with different batches of material. In three of these tests, the material was transported from the field to the laboratory in test tubes closed with a wet plug and a rubber cap. In Experiments Ib and Ic, about 1 g. of material was placed in a Petri dish on the laboratory bench, where it was kept moist by the occasional

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addition of a drop of water, and tested on the day of collection and on the 7th or 8th day. In Experiment Id, 0.2 g. of material was emulsified in 20 ml. of water and the mixture left in a shallow layer in a Petri dish. After 24 hours, half the mixture was centrifuged and the deposit tested on a sheep, the other half being left in the Petri dish and similarly tested on the 7th day. In Experiments Ie to Ih, the material was spread in a thin layer on the inside of an open Petri dish and left exposed to the air to dry.

Summary.

The infective agent remained viable for 24 hours in material from lesions either immersed in water, kept moist or air-dried, but it did not survive four and five days when dried or seven days when kept moist or immersed in water. Of feet treated with material kept not more than 24 hours, 46 out of 47 became infected, whereas none out of nine feet treated was infected with material kept from four to eight days. The single failure in sixteen attempts to infect with fresh material was no doubt due to insufficient dosage.

Table 1.—Viability of Infective Agent in Material from Lesions.

Experiment No.	Infective Material.	Transmission Experiments.					
		On day Collected.		After 24 Hours.		After 4–8 Days.	
		No. of Feet Treated.	No. of Feet Infected.	No. of Feet Treated.	No. of Feet Infected.	No. of Feet Treated.	No. of Feet Infected.
1a ..	Kept moist	..	..	16	16	..	..
1b ..	„ „	16	15 (1)	..	..	2	0 (7 days)
1c ..	„ „	1	1	..	..	1	0 (8 days)
1d ..	In water ..	..	..	2	2	2	0 (7 days)
1e ..	Air-dried ..	2	2	2	2	..	..
1f ..	„ ..	..	..	4	4	..	..
1g ..	„ ..	2	2	..	..	2	0 (4 days)
1h ..	„ ..	2	2	..	..	2	0 (5 days)
All experiments ..		23	22	24	24	9	0

(1) Only very small amount applied to each foot.

(ii) *Viability of Infective Agent in Mud.*

The results of this series of experiments are summarized in Table 2.

Four batches of material from lesions on different sheep were collected, triturated in a mortar, and each divided into two equal lots for mixing with two different soils. In each case 0.2 or 0.25 g. of material was triturated with 10 g. of soil to which had been added sufficient distilled water (5 to 8 ml.) to make a thick paste. The mixtures were then kept in 2-oz. glass jars with screw tops on the laboratory bench.

It was thought that, by using soils of different pH with the same batch of infective material, information might be obtained on the effect of the pH of the soil on the viability of the infective agent. However, after the tests had been completed, the pH values of the residual mud were found to have changed very considerably, so this object was largely defeated. The original and the final pH values are shown in the table.

TABLE 2.—VIABILITY OF INFECTIVE AGENT IN MUD.

Experiment No.	pH of Mud.		Number of Feet Infected after Various Intervals.(*)				
	Before Tests.	After Tests.	24 hours.	3 days.	7 days.	14 days.	21 days.
IIa ..	4·9	6·7	2	2	1 (†)	1 (†)	0
IIb ..	6·8	6·9	2	1	0	0	..
IIIa ..	6·9	7·5	1	..	0	0	0
IIIb ..	7·1	7·7	2	..	1	0	0
IVa ..	5·6	6·6	2	0	0	..	..
IVb ..	7·0	6·7	2	2	0	..	..
Va ..	4·7	7·7	..	..	0	0	..
Vb ..	6·3	7·4	..	..	0	0	..
Total number of feet infected ..			11 out of 12	5 out of 8	2 out of 16	1 out of 12	0 out of 6

(*) Two feet were employed in each test.
(†) It is possible that these infections were due to accidental contagion, since adequate precautions against this were not taken in this experiment.

It will be noted that in Experiment V no tests were carried out to prove that the material was infective, but, as material from lesions has in a large number of experiments always proved infective, it is probably safe to assume that this batch was also infective originally.

The soils used in the experiments, with the exceptions of those used in Experiment IVA and IVB and IIIB, were obtained from properties in three different districts where foot-rot is endemic. The soil used in IIA was from the same paddock as that used in VA. The soil used in IIB contained some sheep faeces. The soils used in Experiments IVA and IVB were from the experimental plot at "Hinchinbrook" in which viability trials described below were conducted. In IVA the natural soil was used; in IVB 0.1 g. of calcium carbonate was added to the 10 g. of soil to bring the reaction to neutral. The soil used in IIIB was from the plot at the laboratory where a test described below was carried out.

Summary.

In all of six tests foot-rot was produced by the application of a mixture of 0.2 or 0.25 g. of material from lesions in 10 g. of soil and 5 to 8 ml. of water after this had been kept on the laboratory bench for 24 hours. Similarly, in three out of four tests foot-rot was produced after keeping the mixtures three days. After seven days the infective agent was demonstrated in two out of eight tests, and in only one instance after 14 days. However, it is possible that the infections apparently produced by the 14-day-old mixture and one of the 7-day-old mixtures were due to accidental contagion since adequate precautions against this were not taken in this experiment. The fact that in four instances only one of two feet treated with the same mixture became infected shows that failure to infect either of two feet in other instances cannot be taken as proof that the infective agent was then dead. However, when all the tests are considered together, the results assume a definite significance; eleven out of twelve feet treated with 24-hour-old mixtures became infected whereas out of eighteen feet treated with mixtures fourteen and twenty-one days old, only one became infected and that one may have been due to accidental contagion. It may be concluded that, under the conditions of the experiments, the infective agent dies in the course of from one to three weeks, probably less than one week in most instances.

(iii) *Viability of Infective Agent in Sheep Faeces.*

In Experiment VIA 0.2 g. of material was mixed with 10 g. of air-dried sheep faeces and 15 ml. of tap water and the mixture kept on the laboratory bench in a closed glass jar. The mixture was applied to two feet on the 7th and on the 14th day and failed to produce foot-rot on both occasions. The 0.2 g. of material used in this test was half of a batch of which the other half was used in Experiment ID where it was shown to be infective. In Experiment VIB 0.05 g. of infective material was mixed with 1 g. air-dried sheep faeces and 1 ml. water. When tested seven days later this mixture produced foot-rot in two feet to which it was applied, but it did not do so after fourteen days.

(iv) *Viability of Infective Agent in Mud and Faeces in a Wet Yard.*

Three experiments, VII, VIII, and IX, were carried out in a pen, measuring 14 ft. 6 in. x 3 ft. 9 in., on the natural earth. Throughout the experiments it was kept thoroughly wetted by hosing daily so that a quagmire of mud and faeces was formed. In each experiment the pen was infected by leaving in it for a week three sheep each with two affected feet. In all three experiments the pen was then left empty for 24 hours after which two test-sheep, each with two feet scarified, were put in.

The soil originally had a pH of 4.8 when used in Experiment VII. The test sheep were in the pen for three weeks but did not develop foot-rot. At the end of the experiment two samples of the mixture of mud and faeces in the pen had pH values of 6.2 and 6.6.

A week before Experiment VIII was commenced, 10 lb. of finely ground limestone was applied to the soil in the pen with the object of bringing the reaction to neutral and possibly aiding the survival of the infective agent. The test sheep were kept in the pen two weeks but did not develop foot-rot. At the end of the experiment the pH of the mud and faeces was found to be 6.8. Experiments VII and VIII were conducted during November and December in warm to hot weather.

Experiment IX. was carried out six months later, during the winter. The test sheep were removed after being in the pen four days and kept under observation. One of them developed foot-rot in both scarified feet and the other in one. The pH of the mud and faeces after the experiment was 6.7.

Summary.

In two experiments carried out during the late spring and summer, the infective agent could not be demonstrated in the muddy floor of a pen 24 hours after removing infected sheep. In a further test carried out during the winter, three out of four scarified feet became infected from the muddy soil on which infected sheep had been 24 hours previously.

(v) *Viability of Infective Agent on Wet Pasture.*

Five experiments (X. to XIV.) were conducted in a quarter-acre plot at "Hinchinbrook," 20 miles inland from Sydney, and one experiment (XV.) in a plot one-tenth of an acre in area at this Laboratory.*

* The F. D. McMaster Animal Health Research Laboratory.

The location of the plot at "Hinchinbrook" was specially selected for the purpose. A small stream ran through it, and produced a swampy patch over an area which varied in extent from one-quarter to two-thirds of the area of the plot. The pasture in the plot was not dense or very long, but the area was mostly covered with short green pasture during all experiments except X., when there was very little green pasture at all.

The general plan of the experiments in this series was to contaminate the soil and pasture by depasturing several sheep infected with foot-rot, remove these and leave the plot unstocked for a period, and then put in several uninfected test sheep to try to detect any infection which may have survived. In all experiments the test sheep's two right feet were scarified when they were put in the plot and again five days later.

Experiment X.

Ten sheep were placed in the plot and both the right feet of each scarified. A small amount of material from foot-rot lesions was applied to the scarified feet of eight of the ten sheep. Five days later the feet of the two sheep to which no material was applied had healed and were scarified again. All the sheep were removed from the plot after being in it 26 days. Fifteen of the sixteen feet on eight sheep to which infective material had been applied had developed foot-rot. One of the other two sheep had developed foot-rot in the two right feet, while the other had not become infected. After the plot had been left unstocked, during warm October weather, for fourteen days, ten test sheep were placed in it. Six of these sheep were removed after being in the plot three weeks and the other four after being in it five weeks. None developed foot-rot.

Experiment XI.

Five sheep, each affected with foot-rot in two feet, were depastured in the plot for fifteen days and then it was unstocked for nine days. Six test sheep were kept in the plot for fifteen days, after which the scarification lesions on their feet had healed and there were no lesions of foot-rot. This experiment was conducted during April when there were heavy dews.

Experiment XII.

The strain of foot-rot used in this experiment was obtained from a different district to that used in the two previous experiments. Five sheep, each with two feet infected, were kept on the plot for nine days. The plot, which was wet and well grassed, was then left unstocked for 24 hours during cool overcast weather in May. Five test sheep were put in for three weeks, but did not develop foot-rot.

Experiment XIII.

Four sheep, each with two feet affected with foot-rot, were placed in the plot together with two uninfected sheep. The right feet of the two uninfected sheep were scarified when they were put in and again five days later. When all the sheep were removed three weeks later, the two sheep which were originally not infected were found to have developed foot-rot in both right feet. This time the plot was left unstocked for nine hours from 7.30 a.m. till 4.30 p.m. on a cool, but sunny, July day. Three test sheep were put in the plot for fifteen days but did not develop foot-rot.

Experiment XIV.

The soil in the plot was now tested and found to have a pH varying from 5.2 to 5.8 in different places. Three hundredweight of powdered calcium carbonate was spread over the quarter-acre plot. Two months later six samples of soil were found to have p.H values varying from 5.4 to 6.6. Then five sheep each with two feet affected with foot-rot were kept in the plot for eighteen days during October. The plot was then left unstocked for 24 hours during which 6 points of rain fell. Five test sheep were put in the plot for four weeks, but none contracted foot-rot.

Experiment XV.

This was conducted in the plot at this Laboratory. The soil had a pH value of 7.1 and showed evidence of having been treated with lime some years previously. During the experiment this plot carried a fairly dense green pasture of clovers and weeds and was kept moist by means of a spray irrigation plant. Three sheep each affected with foot-rot in two feet were placed in the plot for 20 days. After they had been in for five days, an unaffected sheep was also put in and its two right feet scarified then and again seven days later. This sheep had developed foot-rot in both right feet when it was removed with the others. The plot was left unstocked for 24 hours during cool June weather, the pasture and soil being wet. Four test sheep were put in the plot for fifteen days. These sheep each had three feet scarified on two occasions instead of only two feet as in the test sheep in previous experiments. They did not develop foot-rot.

In all these experiments the test sheep were kept under observation for some weeks after being removed from th plots in case they developed foot-rot subsequently, which, however, none did.

Summary.

In four experiments, a small plot which was partly swampy was contaminated by heavily stocking with sheep infected with foot-rot. The plot was then left unstocked for 2 weeks, 9 days, 24 hours, and 9 hours in experiments X, XI, XII, and XIII respectively, after which uninfected test-sheep each with two feet scarified were placed in the plot. In none of the experiments did any of the test-sheep become infected. The plot was then treated with calcium carbonate to reduce the acidity of the soil and another similar experiment (XIV) was conducted, leaving the plot unstocked for 24 hours. Again none of the test-sheep became infected. Experiment XV was conducted in a different plot which carried wet, dense, green pasture and in which the soil had a neutral reaction. Here also infection could not be demonstrated in the pasture and soil after unstocking for 24 hours. On the other hand, of eight feet scarified on four sheep, six developed foot-rot when depastured in the plots together with infected sheep. Thus, sheep whose feet had been scarified usually contracted foot-rot under conditions similar to those to which the test-sheep were exposed but in the presence of known infection.

The fact that none of the test-sheep became infected does not necessarily mean that none of the infective agent survived the periods during which the plots were left unstocked, for relatively small amounts may have survived without being detected by the technique employed. Nevertheless, under the conditions of the experiments, sheep whose feet had

been scarified became infected when run with infected sheep, i.e. on known infected pasture, for from two to three weeks, whereas test-sheep running in the plots for from two to five weeks after they had been unstocked did not become infected; therefore the pasture had apparently lost its capacity to produce foot-rot in sheep running on it.

2. Viability of the Infective Agent in Association with Sheep.

(i) *Viability of the Infective Agent in Lesions of the Disease.*

Foot-rot is typically a chronic disease of long duration unless treated. During several years' experience of the disease in sheep kept on concrete-floored pens, only in a very small proportion of cases has spontaneous recovery been observed and most of these recoveries were probably due to the surgical interference necessary when obtaining infective material for experimentation. Many cases of the disease have been observed over periods of six months and several up to twelve months, and in the majority of cases the disease terminated only when therapeutic measures were employed. Cases of the disease of several months' standing have never failed to yield material capable of setting up new cases when transferred to other sheep.

One sheep was infected in January 1934 and was left untreated until July 1937—a period of three and a half years. One foot was infected during the whole period and another foot for two years and the lesions showed no tendency to heal, although during the last eighteen months the lesions were slightly less severe than is usual. For most of the three and a half years the sheep was in contact with cases more recently affected, but during two periods of several months this was not so. During the last two weeks of the three and a half years, the sheep was isolated in a cage by itself and then material was taken from the lesions and applied to a scarified foot of another sheep. The latter developed typical foot-rot.

Thus, in affected sheep which receive no therapeutic treatment, the infective agent may remain viable and infective for periods of at least three and a half years and quite possibly for as long as the affected sheep lives.

In the field as well as at the laboratory, cases have been found which show under the horn only quite a small focus of infection which might be overlooked during a superficial examination. In one mob of 500, six sheep were found affected although the station manager had thought he had removed all infected animals. He had relied on lameness for diagnosis. Mild lesions may be present without causing lameness.

(ii) *Viability of the Infective Agent on the Feet of Apparently Recovered Sheep Showing Superficial Lesions of the Skin Between the Digits.*

Observation of sheep which were treated curatively at the laboratory revealed that in a few sheep in which the hoof lesions had quite healed mild lesions persisted on the skin between the digits, and the infective agent survived in these lesions for as long as seven months in one sheep. The skin lesions referred to were mild and superficial and caused no lameness but were readily detectable on visual examination of the area. The skin between the digits normally covered with hair was hairless and slightly moist. The area was sometimes red but more often the surface of the skin was covered with a thin layer of opaque, white, necrotic material.

In one sheep which had had foot-rot and was treated with tartar emetic and lanoline, the hoof lesions entirely healed but in one foot the lesions described above persisted. The sheep was isolated from other affected sheep and kept part of the time on a concrete-floored pen and part of the time in a cage with open wooden battens on the floor. From three to five months after the hoof lesions had healed three unsuccessful attempts were made to produce foot-rot in another sheep with material from the skin lesion between the digits. Later, the foot showing the skin lesion was scarified two or three times a week for several weeks and the lesion became more severe and involved the edge of the horn, although typical foot-rot did not develop. However, when material from the lesion was now applied to another sheep's foot which had been scarified, typical foot-rot was produced. The infective agent had survived in the superficial skin lesions for 28 weeks.

In one other sheep, which was isolated from cases of foot-rot, similar lesions persisted for a month after the hoof lesions had been cured, and after this time foot-rot developed again in that foot. In each of three other sheep, similar lesions persisted in one foot for from two to eight weeks after the hoof lesions had healed and then foot-rot developed in these feet. However, these three sheep were in contact with other cases of foot-rot all the time. In one of them the relapse followed the application of Strongyloides larvae. In all these cases *Sp. penortha* was found in smears from the superficial skin lesion. Organism "K"* and the foot-rot fusiform bacillus were also present in smears from the isolated sheep in which the lesions persisted for a month. Unfortunately, smears from the sheep with lesions persisting for seven months were discarded.

On the other hand, in a few cases superficial skin lesions between the digits persisted for a few weeks after healing of the hoof lesions and then the skin lesions healed spontaneously.

In the field, when examining during summer over 2,000 sheep in flocks in which foot-rot was present or had been present, we found only fourteen sheep with no hoof lesions that showed skin lesions between the digits. Smears were obtained from nine of these but only one showed *Sp. penortha* the fusiform and organism "K." Thus it appears that this type of lesion does not occur very commonly in the field.

No attempt has been made to cure the skin lesions described after the hoof lesions had healed. The very superficial nature of the lesions lead one to believe that they would be easily cured by passing the sheep through a foot bath containing a suitable medicament.

It should be clearly understood that these remarks apply only to sheep showing no lesions in the hoof. Other sheep have been found with lesions of the skin between the digits, and, on closer examination of these feet, small lesions have been found under the horn. The condition of the skin between the digits is a useful guide to the presence or absence of infection under the horn, although sometimes infection under the horn is found when the skin is normal.

(iii) *Viability of the Infective Agent on Feet of Recovered Sheep Showing no Lesions.*

Fifty-two feet on 36 sheep which had recovered from foot-rot following treatment with various medicaments were examined from four weeks to four months after recovery and appeared perfectly normal

* See article commencing on page 1.

except for malformation of the hoof in some. These feet were then scarified between the digits and to some were applied cultures of *Fusiformis necrophorus,* to others *Staph. aureus,* while others had no cultures applied but were run on a wet clover pasture. Smears from the lesions so produced showed no *Sp. penortha* and the lesions all healed without the development of foot-rot. These results are taken as indicating that the feet were probably not carrying the infective agent, for recovered sheep are usually susceptible to foot-rot when infected material is applied after scarification.

However, two sheep relapsed one week after having been passed as cured, since their feet showed no abnormality other than mis-shapen hooves which all recently recovered sheep show. In each case a small pocket of infection under the horn had healed over, and this spread to involve the whole foot again.

Another sheep, which had been infected for three and a half years, was treated and passed as cured; when examined one week later it was considered normal except for mis-shapen hooves and a slight moistness of the skin between the digits attributed to the muddy condition of the paddock in which it was running. All four feet had been affected before treatment. The two right feet were scarified and cultures of *Staph. aureus* applied. During the following two weeks one left foot and one right foot developed foot-rot.

While examining over 2,000 sheep in station flocks in which foot-rot had been present, and in some cases still was present, we found four sheep with mis-shapen hooves and healed-over pockets of pus under the horn. These four cases were all in flocks in which there were still some active cases. No measures were taken to determine if this pus contained the infective agent of foot-rot, but it is probable that it did. Superficially, these feet appeared quite healed and showed no evidence whatever of infection until the horn was pared. It is not known how much time had expired since these sheep last showed frank lesions of foot-rot, but they appeared to have "healed over" some weeks previously.

Summary.—These observations show that recently apparently recovered sheep may harbour infection under the horn. In the two cases at the laboratory the infection soon became manifest again, and those encountered in the field were discovered when the mis-shapen hooves were pared. The lesions are not such that they are likely to escape detection, provided all mis-shapen hooves are carefully pared. In the sheep which had apparently recovered after having had the disease three and a half years, the infection became manifest in one foot in the course of three weeks without any interference and in the other foot after scarification. On the other hand, all of the 40 feet which still appeared normal four weeks or more after being passed as cured were apparently free of the infective agent.

(iv) *Viability of the Infective Agent in Other Abnormalities of the Hoof.*

There remain to be considered two other abnormalities of the hoof.

Sheep after recovery from the characteristic lesions of foot-rot occasionally show a discharging sinus above the coronet or between the digits. This is usually the result of involvement of a joint, ligament, or

tendon. No tests have been carried out to determine if the infective agent of foot-rot persists in such lesions. However, these cases are usually very few, and hence, when eliminating infected animals from a flock, it is convenient to regard them as possibly infective and eliminate them.

Another condition of the hoof, which often affects quite a large proportion of the flock, is separation of the outer portion of the wall of the hoof from underlying softer horn. The laminae are covered with dry, healthy, new horn, and between this and the old outer portion of the wall is usually packed soil and faeces. This condition, which may be described as "dry separation," is frequently present in flocks in which there has been no foot-rot. There is no active diseased tissue or pus present. Therefore, there is no reason to believe that the infective agent of foot-rot is likely to be present in these locations. In one such case in a sheep which had had foot-rot and recovered, the dry material under the wall was tested on another sheep's foot. As was expected, it failed to produce foot-rot. Although there is no reason to believe feet showing this abnormality are likely to carry the infective agent, it is advisable to pare away the separated wall when examining sheep for the presence of infection in case an area of active infection is concealed there.

(v) *Viability of the Infective Agent in Skin Wounds on Sheep Elsewhere than on the Foot.*

The skin over the side of the body of a sheep was shaved and deeply scarified. Material from lesions of foot-rot was applied and the area covered with oiled silk. Three days later, pus from the area was applied to two feet of a sheep which had been scarified. Purulent lesions were produced in the feet, but these healed spontaneously without the development of foot-rot.

The skin on the side of the body of another sheep was more severely damaged by searing with a hot spatula under local anaesthesia and also an adjacent area scarified. Material from foot-rot lesions was applied and the area covered with sheet rubber. A week later pus and necrotic skin was removed and applied to two feet on a sheep after scarification. No foot-rot developed in the test animal.

Intradermal inoculations were made at several sites on the side of a sheep with foot-rot material mixed with killed culture of *F. necrophorus*. Pus from the small cutaneary abscesses so produced was applied to two feet, but no foot-rot resulted.

Although these observations are too limited to allow generalization, the conditions are what one would consider favorable for the persistence of the infective agent of foot-rot and yet it did not survive three and seven days. It therefore seems improbable that it would persist in wounds or superficial lesions on the body elsewhere than on the feet. However, the fact that such lesions are seldom of long standing makes it unnecessary to investigate further the possibility of the survival of the infective agent in them. Sheep affected with foot-rot sometimes develop deep ulcerations over the sternum. We have not attempted to demonstate the infective agent of foot-rot in these. However, these ulcers usually heal fairly readily when the feet lesions have been cured.

The Control of Foot-rot in Sheep.

*By W. I. B. Beveridge, B.V.Sc.**

Summary.

Although outbreaks of foot-rot usually occur only under favorable seasonal conditions, the disease is nevertheless a specific, contagious disease, and therefore cannot occur except when the specific causal agent is present. It has been shown that the causal agent cannot survive longer than a few weeks at most apart from the sheep, and therefore the removal, during the summer, of all sheep carrying the infection should entirely free the flock and property of infection. When the infection has been thus eliminated, the disease is not expected to recur unless introduced from outside sources. The details for carrying out such a scheme are discussed.

1. Introduction.

The proposed scheme for the control of foot-rot in sheep by the elimination of the infection from flocks, followed by quarantine measures, is based on the conception of foot-rot as a specific contagious disease. Although for many years it has been recognized as contagious, until recently foot-rot has been fairly generally thought to be caused by *Fusiformis necrophorus,* an organism which probably has an almost universal distribution where domestic animals are kept and is probably a common intestinal inhabitant in herbivora. It is perhaps due to this belief among veterinarians and the belief among most pastoralists in New South Wales that foot-rot is not a contagious disease but is caused by lush pastures *per se,* that hitherto no serious attempts have been made, at least in Australia, to control the condition by the method employed against many other specific contagious diseases of domestic animals. In 1890, in England, Nott contended "that the disease (foot-rot) is only produced by means of contact with a diseased sheep and that the only certain method of preventing it is to avoid the introduction of fresh sheep on to a farm" (Brown 1892). In 1904, Mohler and Washburn advised precautions to avoid introducing the disease to flocks, and stated that sound sheep may be safely depastured on land that had previously been occupied by sheep suffering from foot-rot provided that a winter's frosts had been allowed to intervene.

Experiments carried out by the writer (Beveridge, 1935) have shown that *F. necrophorus* is not the cause of foot-rot nor can the disease be set up by non-specific pyogenic organisms or trauma; furthermore, Brown (1932) and Carne (see Beveridge, 1935) have shown that maceration with water will not produce the disease. In a large series of experiments on the reproduction of the disease carried out by the writer, foot-rot has behaved as a typical specific contagious disease, only developing when the specific causal agent was known to be present. A few observations in the field support this conception. Certain properties in Victoria were free from the disease for many years until it was introduced, and afterwards it became endemic on these properties.

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Quite recent investigations by the writer suggest that foot-rot is caused by a hitherto unrecognized bacterium, organism "K", possibly in association with two other organisms also unrecognized until recently, *Spirochaeta penortha* and a fusiform, and further investigations are now in progress. However, for the purpose of consideration of the control of the disease and the viability of the causal agent, the actual identity of the causal organism need not be taken into account except in so far as it is apparently specific for foot-rot. Therefore, in this report it will be referred to as the infective agent of foot-rot.

Under Australian sheep-raising conditions (with the exception of irrigated farms and possibly some districts in Tasmania, which present a separate problem), foot-rot has a definite seasonal incidence. In the large majority of cases, it occurs when there is a flush of feed, which is usually in the autumn or spring, and new cases do not usually occur during the summer. Thus there are periods when the disease is active and spreading, separated by periods when the disease is either not in evidence or at least not spreading. Therefore, we must consider how the infective agent survives the periods when the disease is not active.

On some properties, a few chronically affected sheep are present throughout the periods when the disease is not spreading, and it is probably from these that fresh outbreaks of the disease occur whenever seasonal conditions become suitable. On other properties the disease appears to die out during the summer or for longer periods, and yet it recurs when conditions again become favorable. In some cases the reappearance of the disease may be due to re-introduction from other flocks, but often evidence of this cannot be obtained, and one must consider how the infective agent has survived the intervening period. In order to devise a scheme for control by elimination of the infective agent, we must consider whether the latter is able to survive for long periods (*a*) apart from the sheep, and (*b*) in association with the sheep.

2. Viability of Infective Agent apart from Sheep.

The first investigations on the viability of the infective agent apart from the sheep were conducted in England in 1892 by Brown, who found that foot-rot developed in sheep placed in a wet yard two days after the removal of infected sheep. More recently, in the United States of America, Marsh and Tunnicliff showed that the infection did not live in the soil of pens for more than fifteen days when it was allowed to dry or for more than 30 days when kept continually wet. In a swamp it appeared to persist in an attenuated form over a period of nine months, but the report of this experiment leaves considerable doubt as to whether the disease which developed in sheep placed in the swamp after this period was really foot-rot.

The writer has conducted an extensive series of experiments to test the viability of the infective agent apart from the sheep and these are described in a separate report.* Briefly, these experiments demonstrated that the infective agent may survive a few days in material from lesions, in mud, or in sheep faeces, but probably never more than three weeks. The infective agent could not be demonstrated in infected

* See page 4.

pastures even nine hours after the removal of infected sheep, although in one out of three experiments it was demonstrated in the mud and faeces of a wet pen 24 hours after the removal of infected sheep.

These experiments show fairly definitely that it would not be possible for the infective agent to survive several months during the summer apart from the sheep.

3. Viability of Infective Agent in Association with Sheep.

The writer's observations in this connexion are also incorporated in the separate report. Briefly it was found that the infective agent may survive (*a*) in lesions of chronically infected animals, which may not necessarily show consistent lameness, for at least three and a half years, (*b*) in superficial skin lesions between the digits of apparently recovered sheep for as long as seven and a half months, (*c*) under the horn in mis-shapen hooves on apparently recovered sheep for at least one week, (*d*) in recovered sheep showing no definite lesions for at least one week. On the other hand, sheep entirely free of any lesions for from four weeks to four months after recovery are apparently free of the infective agent.

4. Control of Foot-Rot.

On properties where the disease breaks out after a period of several months during which it is not in evidence, the new outbreak probably arises from infection surviving in association with sheep and not apart from the sheep, excepting those instances where the infection is re-introduced into the flock.

As a result of these investigations, it is suggested that it will probably be possible to control foot-rot by carefully examining, during the summer, the feet of all sheep on properties where the disease is endemic and eliminating all sheep showing chronic lesions, superficial skin lesions between the digits, or any foci of infection under the horn, and subsequently preventing the re-introduction of infection. January and February is the best time to do this work, since at this time sheep will usually have had at least one month for the majority to recover completely after a spring outbreak of the disease. During this examination, all hooves which are mis-shapen require paring to discover any possible hidden foci of infection. Sheep showing any lesions on the feet other than those mentioned should be regarded with suspicion as possibly carrying the infective agent and should be eliminated at least until the lesions have healed. Sheep with separation of the outer wall from underlying healthy, dry, young horn need not be regarded with suspicion.

As an additional safeguard, the sheep should be passed through a foot-bath containing a suitable medicament, such as copper sulphate or formalin solution, after examination. If at the time of examination the flock has a large percentage of sheep still infected or with mis-shapen hooves or only recovered one or two weeks previously, it may be necessary to make two examinations with an interval of about a month between.

The sheep which have been eliminated during the examination should be isolated immediately. They may be then treated and returned to the flock a month after they have been completely cured, or in some cases it may be convenient to kill them or sell them for slaughter.

Field trials are necessary to prove (*a*) if it is possible to detect every sheep carrying infection, and (*b*) if a flock will remain free from foot-rot after elimination of all animals carrying infection on their feet, provided there is no re-introduction of the disease.

In regard to the latter point, there is no evidence that foot-rot can arise spontaneously as many pastoralists believe. Other specific contagious diseases do not arise spontaneouly after all the sources of the infective agent have been eliminated, although, of course, in certain instances they may arise in the absence of other cases of the disease, the infection originating from organisms present in the environment or from carriers. In the case of foot-rot, there is evidence that the causal agent does not exist or survive long in the environment. Apart from the fact that, in all our experimental work, foot-rot has behaved as a typical specific contagious disease, information obtained in the field shows that a flock free of the disease may remain free for years if it is not introduced. Since it is improbable that foot-rot can arise spontaneously, the chief object of field trials is to determine if it is possible to detect all animals carrying infection; the writer's experience of the disease suggests that by careful work this should be not only possible but comparatively easy.

5. Field Trials.

The writer has found that the most convenient way to arrange field trials with controls is to eliminate the infection from one mob of sheep on the property and leave them isolated and in quarantine in a paddock where ordinarily foot-rot was prevalent, the remainder of the flock on other portions of the property serving as controls. Some twelve trials along these lines have been carried out in New South Wales and Victoria during 1936 and 1937 on properties where outbreaks usually occur every year, but unfortunately during these two years the seasonal conditions have been exceptional and little or no foot-rot has occurred in any of the sheep; therefore no conclusions can be drawn.

It has been found, in conducting these trials, that occasional cases of infection of the feet may occur in the experimental sheep, and the necessity arises of arriving at a definite diagnosis in these cases. Sheepmen cannot be relied on to diagnose isolated cases of foot-rot. A fairly reliable diagnosis can usually be arrived at from examination of the lesions when extensive separation of the horn from the sensitive laminae is present, but when the typical advanced lesions of the disease are not present clinical diagnosis with any certainty is not possible. Examination of smears from the lesions will usually reveal the presence of *Sp. penortha,* a fusiform organism and organism "K" if foot-rot is present. However, the diagnosis should be confirmed by the production of another case of the disease from material taken from the lesions. Material for this purpose may be kept for 24 hours during transport to the laboratory for testing. The lesions produced in the test animal should be typical of foot-rot, show no tendency to heal spontaneously for at least some weeks, and contain the causal organism "K".

Although a flock has been freed of foot-rot, the condition known as "scald" may appear, possibly affecting large numbers of the flock, and care must be taken to differentiate it from foot-rot.

In conducting these field trials, it has been found necessary to impress on the owner or manager that, should any of the experimental sheep show lesions, they must not be treated before the investigator has examined them.

Where the "clean" sheep are in a paddock adjacent to one containing infected sheep, the possibility must be considered of the infection being carried mechanically on horses or men's feet or on the wheels of vehicles. If the sheep congregate on either side of a gate this is a definite possibility.

6. Infection on Pasture.

Where sheep are depastured on natural, un-irrigated pasture in Australia, after elimination of infected animals during the summer, the sheep may usually be returned to the same paddocks without these having been left unstocked. Although some of the infective agent may survive for a few days in the soil, especially around watering places, the sheep will not become infected under the conditions usually prevailing in the summer and the infective agent will die out before conditions become favorable for the development of new cases of the disease. However, if the elimination of infected animals is done during wet weather or during an unusual summer when the pasture is green, the paddocks should be left unstocked for from two to four weeks before the clean sheep are put back on them.

On irrigated pasture and in countries where conditions are such that the disease is contracted at all times of the year, the pasture should be left unstocked for a period of not less than two weeks and preferably three to four weeks before the "clean" sheep are returned to it; otherwise they may contract the disease from the infection persisting on the pasture and soil before it has died out.

7. Control on Irrigated Pasture.

If a high proportion of the flock are affected on irrigated pasture in Australia, it would often be more satisfactory to dispose of all the old flock and after leaving the pasture unstocked for two to four weeks, re-stock with sheep free from the disease. This policy has been put into effect at the Victorian State Research Farm, Werribee, on the advice of the writer. For the previous two years, approximately 60 to 70 per cent. of the flock on irrigated pasture had been affected with foot-rot throughout the year. These sheep were disposed of, and the pasture left unstocked for two weeks and then re-stocked with 200 sheep free from foot-rot. These sheep have been on heavy carrying irrigated pasture since 11th March, 1937, and to date no foot-rot has appeared in them. Since they have remained clean for ten months under conditions very favorable for the contraction of the disease, they should remain free indefinitely, provided no infection is introduced from outside sources. The animals have been passed through a foot-bath on four occasions during this period when being returned to the pasture

after movement through the general yards of the farm, but it is very improbable that this treatment could have entirely protected the sheep from foot-rot had the infection been present on the pastures.

On irrigated properties where it is undesirable to dispose of the sheep and re-stock with uninfected sheep, the disease should be attacked by vigorous treatment in an endeavour to stamp it out. All affected feet should be thoroughly pared and treated with 10 per cent. formalin every two or three days, and unaffected ones passed through a foot-bath of 2 to 5 per cent. formalin until all cases are cured or only a few are left; these can be isolated. When the flock has been freed from infection in this way, every two or three days the sheep should be re-examined for fresh lesions and all passed through a foot-bath of 2 to 5 per cent. formalin or 10 per cent. copper sulphate. After a period of from two to three weeks has elapsed without any cases of foot-rot in the flock, the infection on the pasture and soil will probably have died out and henceforward the flock should remain free.

8. Discussion.

The possibility of the infection living in the alimentary canal of sheep has not yet been discussed. In a large number of experiments, foot-rot has never developed in feet scarified and contaminated with faeces when the infective material has not been applied; therefore, this organism is not a common intestinal inhabitant. However, it is conceivable that the organism may become established in the alimentary canal, perhaps only temporarily, after it has been ingested with contaminated pasture. This possibility seems remote, but it requires investigation, and three small experiments have been carried out on this point. A sheep was drenched with foot-rot material and its feet scarified. Its faeces were allowed to accumulate in a small pen 7 feet by 4 feet to which it was confined. It did not develop foot-rot. In the second experiment the sheep was treated similarly, but a second sheep with two scarified feet was also placed in the pen. No foot-rot developed. The third experiment was the same as the second and the result similar. A large number of such experiments would be necessary before any conclusions could be drawn, especially as it is known that fluids administered to sheep may pass either to the rumen or the abomasum and the path followed may influence the result of experiments of this nature. The experiments described above, however, are of some use, as the results are in agreement with *a priori* considerations.

For reasons discussed in the report on the viability of the infective agent, it is improbable that the infective agent lives for any considerable time in wounds on the sheep elsewhere than on the feet.

There is also to be considered the possibility of animals other than sheep carrying the infective agent. Cattle are subject to a disease of the same name but probably of different aetiology. The lesions of foot-rot in cattle, as far as the writer has been able to ascertain, do not resemble those of foot-rot in sheep. The writer has only had one opportunity to attempt to transfer foot-rot of cattle to sheep, and in this instance foot-rot was not set up in the sheep. Although further evidence on this matter is required, it does not seem very probable that sheep can become infected with foot-rot from cattle suffering from the disease of the same name.

In certain districts in Victoria hares have been observed with diseased feet, and pastoralists have suggested that they may become affected with foot-rot from sheep and carry it from one property to another. The writer applied foot-rot material to the scarified foot of a hare at the laboratory and applied a bandage. Six days later pus from the lesion was applied to a scarified sheep's foot where it did not produce foot-rot. Other experiments indicate that the causal organism of foot-rot is very specific for sheep's feet, and hence it is not likely that animals other than sheep would carry it, except mechanically.

Mechanical transference of the infection from one property to another by birds, dogs, hares, rabbits, or flies is quite conceivable, but the risk is probably so small as to be negligible. As mentioned previously, there is quite a possibility that mechanical transference of infection may occur over very short distances, such as through gateways, on the feet of horses or men, or on the wheels of vehicles. It is also conceivable that infection may pass from one paddock to another in storm or swamp water, but the dilution of the infective material would probably be so great that this is not likely to constitute a serious risk. Running streams could probably not carry infection, since aeration and dilution would probably render the material non-infective.

If the proposed control scheme proves effective, it will eventually become necessary for the proper authorities to frame regulations to enforce the control of foot-rot. But it should be pointed out that the placing of restrictions on travelling stock would not be of much value until most of the properties in districts where the disease in endemic had eliminated the infection. Although foot-rot is a contagious disease, at present most outbreaks probably start from the infection already present in the flocks in areas where it is endemic, rather than from travelling stock. However, in some districts, such as central western New South Wales, outbreaks occur several years apart in exceptionally wet seasons, and it seems likely that these arise from introduced infection. It is not probable that the infection would persist in the sheep on the properties for such long intervals as often occur between outbreaks in these districts. These areas where foot-rot is not endemic might be protected by preventing the introduction of infected sheep.

Where infected sheep have passed over a road or through yards, the soil may remain infective for other sheep passing over it for a few days. The experiments on the viability of the infective agent indicate that soil so infected may be a source of danger for at least 24 hours, and possibly for two weeks when the soil is wet.

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Skeleton Weed, *Chondrilla juncea* L. Experiments with Weed-killers.

By A. B. Cashmore and K. G. Carn†.*

Towards the end of 1934, a Committee was set up to assist in the co ordination of the weeds work of the New South Wales Department of Agriculture and of the Council for Scientific and Industrial Research. The Committee, which is representative of the two bodies, decided to concentrate its attention first on skeleton weed, and drew up a programme of investigation which has been carried out as a joint enterprise. Some of the results of that work appear below.—Ed.

Summary.

The field experiments described in this paper were designed to test chemical weed-killers as a means of controlling skeleton weed; they were commenced in the Wagga district of New South Wales in 1935.

The results of the experiments, which involved 36 treatments, showed that only common salt and sodium chlorate caused reductions in weed plant numbers sixteen months after application.

These substances, in the heavier applications used, adversely affected the establishment of the subsequent wheat crop and the yield of grain. It is suggested that their effectiveness was due mainly to general soil sterilization and absorption through the roots, and not to a direct killing effect as foliage sprays.

The use of sulphuric acid sprays on the skeleton weed-infested wheat crop did not lead to increased grain yields.

The work is being continued.

1. Introduction.

The problem of skeleton weed control in the south-western districts of New South Wales had become a very real one by 1935. A joint Weeds Committee, including representatives of the New South Wales Department of Agriculture and of the Commonwealth Council for Scientific and Industrial Research, was appointed in that year to co-ordinate work on weed control in New South Wales, and it included increased attention to skeleton weed in the programme of work. Among the experiments planned and begun in 1935, in a co-operative effort between officers of the New South Wales Department and of the Council, was a complete review of available weed-killers in relation to skeleton weed destruction. The results of the first year's work with chemicals are reported in this paper.

To review the position briefly, it may be noted that the first record of the occurrence of skeleton weed in New South Wales is contained in a note in 1918 by Maiden (11), in which he gives the identification

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of a plant specimen received from Marrar, New South Wales, as *Chondrilla juncea,* L. Somewhat later, the weed was reported from the Cowra district. Its introduction is thought to have occurred with the importation of impure seed, or, more probably, with fodder received from the United States of America during the 1914 drought period.

In its native habitat, which embraces most of Europe, Asia Minor, Caucasus, and Central Asia, *Chondrilla juncea* is found occupying rocky, conglomerate, and rubbly soils associated with mountain systems and sands, sandy steppes, and deposits of alluvial soils with sandy and stony substrata (8). It is found, too, on cultivated soils and in sown crops, but never in such dense association as on cultivated ground in the Riverina, New South Wales. In the United States of America the distribution of skeleton weed or "gum succory" extends from the middle Atlantic States inland to West Virginia. It is not considered a serious weed pest there (7).

Until 1927, skeleton weed attracted little attention in New South Wales, but in that year it was found widely in the Riverina and south-western slopes divisions of the State (5). In 1935, the distribution of the weed and its effect on the wheat-growing industry were reviewed by Judd and Carn (9). Their distribution map shows that the area infested includes the greater part of the best wheat-growing country of the State. The bare fallow-wheat rotation so generally adopted in New South Wales wheat-farming seems particularly suited to the vigorous growth and spread of skeleton weed. The wheat-growing soils of the Wagga district are typically red brown earths associated with open savannah woodlands (13). The rainfall is more or less uniform with maxima in June and October. The driest month is January with 1.41 inch. Over a period of 59 years the average annual rainfall at Wagga Wagga is 21.33 inches (1).

In 1935, the New South Wales Government offered a reward of £5,000 for any practicable method of eradicating the weed. The conditions attached to the payment of the reward stipulated, among other things, that the effective treatment should not cost more than £2 per acre to apply and that the subsequent fertility of the soil should not be depressed by more than 10 per cent.(2). The entries received invariably suggested chemical treatment. It was decided that any suggestions made in these entries, and not already included as treatments in the prepared experimental schemes, should be tested along with the standard weed-killing chemical treatments.

2. Experimental Procedure.

Two areas of typical wheat-growing land were selected for use in the principal experiments with weed-killers. The first, on a privately owned farm near Coolamon, had been cropped with wheat in 1934 and was found, at the time of application of the treatments, to be carrying a weed population of 1.06 established plants and 24.6 seedlings per square link. In terms of ground cover, skeleton weed occupied 52 per cent. of the total area. This was considered very heavily infested land. The second area, on which the residual effect of the chemical treatments

was to be tested, was located at the Wagga Experiment Farm, Bomen, and was weed-free. A crop had been grown on this area in 1934. Similar treatments were to be applied at both centres, the experimental design including 40 treatments distributed within four randomised blocks. Individual plots measured 50.7 by 4 yards. These were so arranged that, in harvesting the subsequent wheat crop in 1936, one cut of the harvester along the centre of each individual plot removed the grain from approximately 1/40 acre.

The following treatments were included in the plan of experiment:—

	per acre
1. Sodium chlorate	100 lb. in October.
2. Sodium chlorate	150 „ in October.
3. Sodium chlorate	100 „ in December.
4. Sodium chlorate	150 „ in December.
5. Sodium chlorate	200 „ 100 lb. in October. + 100 lb. in December.
6. Sodium chlorate	200 „ 50 lb. in October. + 150 lb. in December.
7. Sodium chlorate	200 „ 100 lb. in October. + 100 lb. after mowing in December.
8. Sodium chlorate	200 lb. 50 lb. in October. + 150 lb. after mowing in December.
9. Sodium chlorate	28 „ applied as dust with 5 cwt. lime per acre (6).
10. Atlacide	28 „ applied as dust with 5 cwt. lime per acre.
11. Atlacide	100 „ in October.
12. Weedex	100 „ in October.
13. Arsenic pentoxide ..	100 „ in October.
14. Arsenic trioxide	5 „ in October—applied as acid sodium arsenite (3).
15. Ammonium thiocyanate ..	100 „ in October.
16. Ammonium sulphate ..	200 „ in October.
17. Ammonium sulphate ..	150 „ in October.
Ferrous sulphate ..	50 „ in October.
18. Sulphuric acid	100 „ in October.
19. Robert's pear poison ..	100 „ in October—applied in concentrated form.
20. Common salt	5 tons in October.
21. Sodium chlorate	100 lb. in October—with glue 3 oz.
22. Arsenic pentoxide ..	100 „ in October—with glue 3 oz.
23. Sodium chlorate	100 „ in October—with Agral I. 6 oz.
24. Arsenic pentoxide ..	100 „ in October—with Agral I. 6 oz.
25. Sodium chlorate	100 „ in October—with Agral II. 3 oz.
26. Arsenic pentoxide ..	100 „ in October—with Agral II. 3 oz.
27. Sodium chlorate	100 „ in October—with soft soap 3 lb.
28. Arsenic pentoxide ..	100 „ in October—with soft soap 3 lb.
29. Sodium chlorate	100 „ in October—with calcium caseinate 2 lb.
30. Arsenic pentoxide ..	100 „ in October—with calcium caseinate 2 lb.
31–39. Entries for Government reward.	
40. Control.	

Except where indicated, the chemicals were applied in solution at the rate of 100 gallons per acre, sufficient liquid to give a light even cover. The October spraying period (14th to 16th October) corresponded to the late stem-initiation stage in skeleton weed, and the December period (4th and 5th) to early flowering.

Some changes became necessary in carrying out the work. Supplies of ammonium thiocyanate were not available, so that treatment 15 could not be applied. The same treatments, with the exceptions of numbers 7 and 8, were applied to the weed-free area as to the infested land, and within two days in each spraying period. The re-growth of skeleton weed following the October spraying was not sufficient to

warrant mowing in treatments 7 and 8. For that reason, the second spraying was not given on the infested area, although it was applied in the weed-free plots. Treatment 37 (mown 5th December and sprayed with sodium chlorate at the rate of 100 lb. of sodium chlorate per acre twelve days later) was included in place of numbers 7 and 8. Only two entries containing useful suggestions were received in competition for the Government reward and were used in these experiments. One, a weed-killer, was applied at four different rates—treatment 31 on 5th December and treatments 32, 33, and 39 on 17th December, and the second, an ingenious arrangement of rotary brushes for attachment to a mower and for use with any weed-killer (Studley's method), was used with sodium chlorate solution on 5th December. Copper sulphate, at the rate of 100 lb. per acre, was included as treatment 34 and was applied on 4th December. In the absence of further useful entries for the reward, numbers 36 and 38 were not allotted treatments and were left unsprayed. The weather at spraying time was on all occasions warm and sunny. It was planned to measure the effects of treatments by means of periodic plant counts and by the yields of wheat grain obtained from the plots when cropped during the following (1936) season.

A further experiment was carried out in 1936 to study the possibility of controlling skeleton weed in the growing crop by means of acid sprays. Sulphuric acid is used on a wide scale in Europe and America for the control of annual weeds, particularly Cruciferous weeds, in crops (4, 10, 12). It was thought that spraying the infested crop with acid might have an effect in reducing the competition capacity of the perennial skeleton weed. To test this point, an experiment involving four treatments distributed in randomised blocks was undertaken at the Wagga Experiment Farm. The following treatments were applied to skeleton weed-infested wheat on 7th August:—

1. Control.
2. Sulphuric acid— 5 per cent. by weight, 100 gallons per acre.
3. Sulphuric acid—10 per cent. by weight, 100 gallons per acre.
4. Sulphuric acid—15 per cent. by weight, 100 gallons per acre.

3. Results.

(a) The Effect of Weed-killers on Skeleton Weed.

To measure the immediate effects of the treatments applied, plant counts were made on 18th February, 1936. In making the counts ten square link samples per plot were taken, and the analysis of variance applied to the means. The experimental area was ploughed during the autumn and sown to wheat (60 lb. seed and 75 lb. superphosphate per acre) on 9th May. Plant counts were again made on 27th July to determine the numbers of skeleton weed plants present at that time and to discover the effects of treatments on the early establishment of wheat. It was not possible to obtain yields at harvest time. The early summer of 1936 in the Wagga district was abnormally wet, and the consequent prolific growth of skeleton weed on practically all plots rendered harvesting virtually impossible. Plant counts were again made on 24th February, 1937, and the experiment terminated. The plant counts results are presented in Table 1.

TABLE 1.—SHOWING RESULTS OF PLANT COUNTS MADE ON WEED-KILLER PLOTS NEAR COOLAMON, 1936-37 (PLANTS PER SQUARE LINK).

Treatment.	18th February, 1936.	27th July, 1936.		24th February, 1937.
	Weed.	Weed.	Wheat.	Weed.
1. Sodium chlorate, 100 lb., October ..	2·18	4·0	3·7	2·50
2. Sodium chlorate, 150 lb., October ..	0·70	1·8	3·5	1·93
3. Sodium chlorate, 100 lb., December ..	6·55	6·0	3·2	2·75
4. Sodium chlorate, 150 lb., December ..	1·93	2·9	3·3	2·38
5. Sodium chlorate, 200 lb., October–December	0·23	0·9	4·2	0·95
6. Sodium chlorate, 200 lb., October–December	0·65	1·6	3·3	1·38
7. Sodium chlorate, 100 lb., October ..	0·78	2·2	3·7	1·85
8. Sodium chlorate, 50 lb., October ..	2·50	3·4	3·7	2·93
9. Sodium chlorate, 28 lb., October ..	3·45	4·8	4·3	2·65
10. Atlacide, 28 lb., October	7·93	5·7	3·7	2·85
11. Atlacide, 100 lb., October	3·08	4·1	3·2	2·65
12. Weedex, 100 lb., October	5·58	4·2	3·9	2·63
13. Arsenic pentoxide, 100 lb., October ..	3·40	4·9	4·0	2·30
14. Arsenic trioxide, 5 lb., October ..	7·70	5·4	3·3	2·60
16. Ammonium sulphate, 200 lb., October ..	5·85	5·2	3·7	3·58
17. Ammonium sulphate, 150 lb., October .. Ferrous sulphate, 50 lb., October ..	7·68	6·0	3·3	2·58
18. Sulphuric acid, 100 lb., October ..	5·40	5·0	4·2	3·75
19. Robert's pear poison, 100 lb., October ..	8·90	4·6	4·3	3·08
20. Common salt, 5 tons, October ..	0·18	0·0	1·5	0·20
21. Sodium chlorate, with glue, 100 lb., October	0·95	3·1	4·0	2·40
22. Arsenic pentoxide, with glue, 100 lb., October	5·73	5·8	4·5	2·30
23. Sodium chlorate, with Agral. I., 100 lb., October	0·53	1·9	3·8	2·08
24. Arsenic pentoxide, with Agral I., 100 lb., October	3·88	5·5	4·0	2·98
25. Sodium chlorate, with Agral II., 100 lb., October	1·28	3·3	4·1	2·13
26. Arsenic pentoxide, with Agral II., 100 lb., October	2·88	3·3	3·7	2·83
27. Sodium chlorate, with soft soap, 100 lb., October	1·00	2·1	3·9	2·10
28. Arsenic pentoxide, with soft soap, 100 lb., October	2·93	4·1	3·7	3·20
29. Sodium chlorate, with calcium caseinate, 100 lb., October	1·18	3·0	4·0	2·33
30. Arsenic pentoxide, with calcium caseinate, 100 lb., October ..	3·18	3·1	3·9	2·38
31. Hardy's weed-killer, 190 lb., December	9·48	2·6	3·3	1·70
32. Hardy's weed-killer, 112 lb., December	16·43	3·7	3·4	2·35
33. Hardy's weed-killer, 117 lb., December	16·85	3·1	4·5	1·60
34. Copper sulphate, 100 lb., December ..	8·53	5·7	4·0	2·83
35. Sodium chlorate, Studley's method, 22½ lb., December	13·15	5·2	3·7	3·00
37. Sodium chlorate, 100 lb., December ..	4·48	3·1	3·9	2·45
39. Hardy's weed-killer, 87 lb., December ..	16·73	4·3	3·7	3·15
40. Control	15·05	5·5	3·8	2·60
General mean	5·37	3·9	3·7	2·45
Standard error	1·94	0·78	0·34	0·39
Standard error—per cent.	36·10	20·0	9·2	15·90

Reference to Table 1 shows that common salt at the rate of 5 tons per acre was the most effective treatment used, as measured by the relative scarcity of weed plants on the treated areas at each time of counting. In the first count after spraying (February, 1936), the common salt was followed in order of effectiveness by eleven sodium chlorate treatments and then by arsenic pentoxide. All plots other than those treated with Hardy's weed-killer and sodium chlorate applied by Studley's method carried significantly fewer plants than the controls. Heavy January rains in this year aided the establishment of skeleton weed seedlings. Of the mean number of weed plants over all treatments (5.37 per square link), 1.27 were established plants and 4.11 seedlings. The density limit for established plants appears to be approximately two per square link. The use of spreaders did not increase the effectiveness of sodium chlorate or of arsenic pentoxide sprays. Sodium chlorate gave significantly better control than did arsenic pentoxide. Over all comparable treatments the mean number of weed plants per square link with chlorate was 1.19 and with arsenic pentoxide 3.67 with a standard error of 0.79 plants. The results suggest that spraying in October is likely to be more effective than spraying at the early flowering stage.

Table 1 shows that in the July following spraying the population of weed plants on fourteen treatments was still significantly less than that on the control, and that the order of effectiveness was similar to that noted in February except that Hardy's weed-killer (treatment 31) had advanced to eighth place where before it was apparently no better than the control. The mean number of plants on the chlorate plots in July was 2.6 as compared with 4.5 on the arsenic pentoxide treatments and the standard error 0.35 plants, again a significant difference in favour of sodium chlorate. The only treatment to have a significant effect in depressing the establishment of wheat seedlings was common salt.

At the termination of the experiment, in February, 1937, the only treatments on which weed plant numbers were less than on the control were common salt and sodium chlorate applied at the rate of 200 lb. per acre (treatments 5 and 6—Table 1). The remaining treatments had had no lasting effect. The results taken collectively indicate that, of the treatments employed, only common salt at the rate of 5 tons per acre and sodium chlorate at 200 lb. per acre gave any definite measure of control of skeleton weed in this experiment.

(*b*) *The Residual Effect of Weed-killers on Soil Productivity.*

The sprayed area of weed-free land was ploughed in March and sown on 24th April, 1936, with 60 lb. wheat and 70 lb. superphosphate per acre. Counts were made on 29th July to determine the effect of the treatments on the establishment of the wheat, and the plots were harvested in December. The results of the plant counts and the yields per treatment are presented in Table 2.

TABLE 2.—SHOWING THE EFFECT OF WEED-KILLERS ON THE SUBSEQUENT ESTABLISHMENT OF WHEAT PLANTS AND ON SOIL PRODUCTIVITY.

Treatment.	Wheat Plants per square link, 29th July.	Mean Yield per plot (lb.).
Per acre.		
1. Sodium chlorate, 100 lb., October	3·7	11·50
2. Sodium chlorate, 150 lb., October	2·9	5·25
3. Sodium chlorate, 100 lb., December	3·2	14·13
4. Sodium chlorate, 150 lb., December	2·7	8·13
5. Sodium chlorate, 200 lb., October and December	2·5	2·50
6. Sodium chlorate, 200 lb., October and December	3·1	7·00
7. Sodium chlorate, 200 lb., October and December	2·2	3·88
8. Sodium chlorate, 200 lb., October and December	2·5	2·25
9. Sodium chlorate, 28 lb., October	3·4	15·13
10. Atlacide, 28 lb., October	3·3	14·50
11. Atlacide, 100 lb., October	3·2	16·38
12. Weedex, 100 lb., October	3·4	15·25
13. Arsenic pentoxide, 100 lb, October	3·9	16·00
14. Arsenic trioxide, 5 lb., October	3·1	12·63
16. Ammonium sulphate, 200 lb., October	3·8	18·75
17. Ammonium sulphate, 150 lb., October Ferrous sulphate, 50 lb., October	3·9	19·38
18. Sulphuric acid, 100 lb., October	3·7	13·88
19. Robert's pear poison, 100 lb., October	3·7	17·50
20. Common salt, 5 tons, October	2·8	8·50
21. Sodium chlorate, with glue, 100 lb., October	3·5	13·38
22. Arsenic pentoxide, with glue, 100 lb., October	3·7	15·38
23. Sodium chlorate, with Agral I., 100 lb., October	3·6	14·50
24. Arsenic pentoxide, with Agral I., 100 lb., October	3·4	16·25
25. Sodium chlorate, with Agral II., 100 lb., October	3·0	15·88
26. Arsenic pentoxide, with Agral II., 100 lb., October	3·4	15·50
27. Sodium chlorate, with soft soap, 100 lb., October	3·5	15·50
28. Arsenic pentoxide, with soft soap, 100 lb., October	3·5	16·25
29. Sodium chlorate, with calcium caseinate, 100 lb., October	3·5	16·88
30. Arsenic pentoxide, with calcium caseinate, 100 lb., October	3·7	15·25
31. Hardy's weed-killer, 190 lb., December	3·1	12·63
32. Hardy's weed-killer, 112 lb., December	3·7	13·13
33. Hardy's weed-killer, 117 lb., December	3·0	14·38
34. Copper sulphate, 100 lb., December	3·0	12·13
35. Sodium chlorate, Studley's method, 22½ lb., December	3·4	14·63
37. Sodium chlorate, 100 lb., December	3·5	14·63
39. Hardy's weed-killer, 87 lb., December	3·1	13·75
40. Control	3·4	12·75
General mean	3·2	13·12
Standard error	0·31	1·10
Standard error—per cent.	9·6	8·39

Reference to Table 2 shows that the only definite reduction in the establishment of wheat seedlings, as measured by plant counts in July, occurred on treatment 7 (200 lb. sodium chlorate per acre). Compared with the control, the reductions noted on the remaining chlorate treatments, where 150 lb. or more per acre was applied and with common salt, approach significance. Significant losses in subsequent crop yield were obtained where 150 lb. or more per acre of sodium chlorate was used and with common salt. With some treatments significant increases in yield were obtained also. Sulphate of ammonia, sulphate of ammonia plus ferrous sulphate, Robert's pear poison, sodium chlorate (treatment 29), Atlacide (treatment 11), and arsenic pentoxide (treatments 24

and 28) stimulated subsequent crop yields. It is doubtful if the increases noted with sodium chlorate, Atlacide, and arsenic pentoxide, which just reach the level of significance, represent real effects.

(*c*) *The Effect of Sulphuric Acid Applied to a Weed-infested Crop.*

The sprayed crop was harvested in December, 1936. The results are presented in Table 3. .

Table 3.—Showing Effect of Sulphuric Acid Sprays on the Subsequent Grain Yield of Skeleton Weed-Infested Wheat.

Treatment.	Nil.	5 per cent. Acid.	10 per cent. Acid.	15 per cent. Acid.	General Mean.	Standard Error.
Mean yield per plot (lb.) ..	3·63	4·38	4·75	5·00	4·44	0·55
Mean yield per plot (per cent.)	81·8	98·6	107·0	112·6	100·0	12·4

Reference to Table 3 shows that there are no significant differences in yield, although a general trend is shown, the yield of grain tending to increase with the increasing strength of the acid solution used.

4. Discussion.

The results of the experiments reported in this paper show that, of the 36 chemical treatments applied to skeleton weed, only three had any permanent effect over the test period in reducing the weed population on the experimental area. Of these, two involved the use of sodium chlorate and one the use of common salt.

The cost of material was of some importance in determining the quantities used. Common salt at the rate of 5 tons per acre costs approximately £20 per acre for material alone at Wagga, and sodium chlorate at 200 lb. per acre more than £5. The cost involved prohibits their use where weed-infestation is extensive, but in isolated areas where fresh infestations occur the cost both of material and of application suggests the use of sodium chlorate in preference to common salt. Arsenic pentoxide and Hardy's weed-killer gave some evidence of control temporarily. Solutions containing sulphuric acid rapidly killed the top growth but had no lasting effect. When used as sprays on the skeleton weed-infested wheat crop, acid solutions did not lead to significantly increased yields of grain, although there was a tendency towards increased yields with increasing concentration of the acid used. No evidence of improved weed destruction was obtained from the use of wetting and spreading agents with sodium chlorate and arsenic pentoxide, although the mechanical work of spraying was facilitated by their use.

Sodium chlorate had an injurious effect on the establishment of wheat when applied at the rate of 200 lb. per acre to the soil some six months before sowing the crop, and, at 150 lb. and 200 lb. per acre, was responsible for a definite reduction in soil productivity as measured by the yield of grain. Common salt also reduced the yield of the subsequently grown wheat crop and appeared to inhibit wheat seedling establishment to some extent.

The evidence obtained suggests that the effectiveness of sodium chlorate and common salt results from general soil-sterilisation and only partly, if at all, from any direct killing effect. Treatments which had no effect on subsequent soil productivity also had no effect in destroying skeleton weed in these experiments. The increased yields obtained following applications of ammonium sulphate were to be anticipated on stubble land (14). No explanation can be given of the apparently stimulating effect on yield of Robert's pear poison applied to the soil some months before seeding.

Further work is in progress to complete a review of the available weed-killers for skeleton weed control. Additional chemicals and greater quantities of sodium chlorate, arsenic pentoxide, and arsenic trioxide (as acid sodium arsenite) are being used to determine their effects in destroying the weed and on subsequent soil productivity. Experiments to determine the stage of growth at which weed-killers may be most effectively applied in the field are also being conducted.

5. Acknowledgments.

The authors acknowledge the continued co-operation of the officers of the Wagga Experiment Farm, and particularly the assistance given by the late Manager, Mr. Hugh Ross, and by Mr. T. P. Taylor, who was Farm Experimentalist when these trials were begun. Our appreciation is expressed too to the members of the Weeds Committee set up by the New South Wales Department of Agriculture and the Council for Scientific and Industrial Research for their advice and co-operation.

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The Effect of the Mules Operation on the Incidence of Crutch Strike in Ewes.

An Interim Report on a Current Trial at "Dungalear" Station.

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1. Introduction.

Notes on the various trials of Mules operation by the Council for Scientific and Industrial Research, the New South Wales Department of Agriculture, and others, were published by Mackerras (1937). As he states, accurate records of the effect of the Mules operation on the incidence of breech strike are difficult to obtain except in relatively small flocks. This year, however, an opportunity was afforded by Mr. J. A. Campbell of "Dungalear" Station, Walgett, to procure accurate data on an experimental group of 650 ewe weaners.

While this trial, which commenced in July, 1937, will continue till July next, the results to date have been so good that they warrant the publication of a brief interim report. It is desirable to stress that the present note is only intended to give a brief outline of the experiment and a synopsis of the results so far attained. A complete and detailed account will be published after the completion of the trial.

(i) *Selection of Experimental and Control Groups.*

The sheep available for the trial comprised 762 Merinos, of which 613 were ewe weaners (born November-December, 1936) and 149 were ewe hoggets (born November-December, 1935). They were shorn in June and were crutched on July 11th, the day before that on which the trial commenced.

One hundred and twelve of these sheep were rejected from the experiment at the outset, the grounds for rejection being (i) that they had already received the station's cull mark, (ii) that they would inevitably be culled at the next classing, and (iii) that already they had been severely struck. The remaining 650 head were classified into "A's", "B's", and "C's", according to the classification of Seddon, Belschner, and Mulhearn (1931). This was done by Dr. J. H. Riches of the Division of Economic Entomology, Canberra, by drafting through a race, and the groups so obtained were then examined more closely by Dr. Riches and the writers, when any animals which had been wrongly classed were re-grouped. The numbers in the three groups so obtained were: "A's"—40 (6 per cent.); "B's"—208 (32 per cent.); "C's"—402 (62 per cent.).

Each of the three groups was then put through a drafting race, and one of each pair as they came through was allocated at random to

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one or other of two numerically equal sub-groups. To obviate any possibility of subconscious selection being exercised, it was then decided by the toss of a coin which of each pair of sub-groups should be operated upon and which should serve as a control. There were thus six sub-groups, three of which were treated and three untreated.

(ii) *The Operation.*

Mr. J. H. W. Mules, who was with us throughout the initial stages of the trial, himself performed the great majority of the fold removal operations. Such as were done by others were carried out under his supervision and to his satisfaction. Rolcut secateurs were used for the removal of the folds. In addition to fold removal Mr. Mules also attempted to correct faulty docking and the more marked instances of distortion of the vulva among the treated groups.

A numbered ear-tag was applied to each sheep, in both control and experimental groups, and notes were made concerning each sheep regarding the extent of the operation (in the case of the treated sub-groups), the condition of the breech, shape of the vulva, and existing evidence of urine staining or faecal staining of the breech.

(iii) *Subsequent Supervision of the Sheep and Recording of Strikes.*

The flock of 650 plus the 112 discarded sheep were grazed as a single unit and were under the special care of Mr. W. Stephens, H.D.A., of the Dungalear staff. A special loose leaf notebook was provided, on each sheet of which was an impression drawing of the breech and adjacent area of a sheep and room for a note to be made of the struck sheep's ear-tag number, the date, and any special comment. The situation of the strike was indicated by marking the impression drawing.

The flock was kept under as careful observation as possible and was mustered for closer examination at fortnightly intervals.

In addition, one of us (N.P.H.G.) visited the property in September and again when the flock was crutched on October 11th. The results recorded below are those for the period July 12th to October 11th. Strikes have occurred throughout, but there was a moderately severe "fly wave" during September and October.

For the purpose of assessing the protection afforded by the fold removal operation, the strikes were classified as far as possible into those originating on the tail and those originating on the medial breech fold. In some few instances the origin of the primary strike was doubtful (see Table 3).

2. Results.

(i) *Tail Strikes Recorded and Strikes of Doubtful Origin.*

In all there were 188 of the total of 650 sheep struck during the period of observation, but since this trial is concerned with the effect of Mules operation for fold removal on the incidence of *breech strikes* we must first consider how many of these sheep were struck primarily on the tail—an occurrence which the removal of the breech fold cannot be

expected to prevent. As may be seen from Table 1 there were 37 sheep that were certainly struck on the tail and a further 24 in which the original site of the strike could not be determined.

TABLE 1.—NUMBER OF SHEEP STRUCK ON TAIL AND STRIKES OF DOUBTFUL ORIGIN.

Breech Classification.	Untreated.					Treated.				
	Number of Sheep in Sub-group.	True Tail Strike.	Probable Tail Strike.	Probable Breech Strike.	Massive Strike. No clue to Original Site.	Number of Sheep in Sub-group.	True Tail Strike.	Probable Tail Strike.	Probable Breech Strike.	Massive Strike. No clue to Original Site.
A	20	0	0	0	0	20	0	0	0	0
B	104	8	1	2	2	103	2	3	0	0
C	201	12	4	5	2	200	15	1	3	1
Total ..	325	20	16			323*	17	8		

* Two sheep from among those treated have died since the trial commenced. The cause of death was not determined, but there was no reason to suppose that death was in any way connected with the operation.

(ii) *Breech Strikes.*

If the strikes of doubtful origin are included as breech strikes, it may affect the apparent value of the Mules operation as a preventative. On the other hand, if they are taken as tail strikes it is equally inclined to influence the apparent results of the operation. In the following tables dealing with the incidence of breech strike, therefore, the doubtful strikes have been included as breech strikes in the one case and omitted from consideration in the other.

TABLE 2.—INCIDENCE OF BREECH STRIKES, OMITTING DOUBTFUL CASES.

Breech Classification.	Untreated.			Treated.		
	Number of Sheep in Sub-group.	Number of Sheep Struck.	Percentage of Sheep Struck in Sub-group.	Number of Sheep in Sub-group.	Number of Sheep Struck.	Percentage of Sheep Struck in Sub-group.
			%			%
A	20	0	0	20	0	0
B	104	22	21·2	103	0	0
C	201	96	47·8	200	9	4·5
Total ..	325	118	36·3	323	9	2·8

As shown in this table the incidence of undoubted breech strike was 2.8 per cent. amongst the treated sheep compared with 36.3 per cent. among the controls, i.e., for every treated sheep that was struck on the breech there were over twelve similarly struck among the untreated groups.

TABLE 3.—INCIDENCE OF BREECH STRIKES, INCLUDING ALL DOUBTFUL CASES AS BREECH STRIKES.

Breech Classification.	Untreated.			Treated.		
	Number of Sheep in Sub-group.	Number of Sheep Struck.	Percentage of Sheep Struck in Sub-group.	Number of Sheep in Sub-group.	Number of Sheep Struck.	Percentage of Sheep Struck in Sub-group.
			%			%
A	20	0	0	20	0	0
B	104	27	26·0	103	3	2·9
C	201	107	53·2	200	14	7·0
Total ..	325	134	41·2	323	17	5·3

It is apparent from a comparison of Tables 2 and 3 that the inclusion of strikes of doubtful origin as breech strikes does not materially affect the results.

(iii) *Particulars of Breech Strikes in Treated Sheep.*

As may be seen in Table 2 above, there were nine sheep in the treated group which were struck on the breech, and it is interesting to consider these individually with the object of determining, if possible, why they were struck in spite of the fold removal operation. The sheep concerned and the result of the examination may be set out as follows:—

Nos. 159, 194, 200, 216, 237, 294.—Portion of fold not removed at time of operation.

No. 253.—Struck on operation wound prior to healing and not re-struck.

No. 300.—Struck at junction of tail fold and thigh.

No. 246.—Dead. Cause of srike not determined.

It is thus seen that of the nine treated sheep which were struck on the breech six were struck because the operation had not been adequately performed. The remaining portion of the fold was removed at the October crutching when these records were procured.

This observation demonstrates the necessity of re-examining sheep on which the Mules operation has been performed in order to detect and rectify any instances in which the operation has been inadequate.

(iv) *Incidence of Re-strikes on Breech.*

During this phase of the trial, the struck sheep were not shorn off in the usual way, the struck areas being carefully and copiously dressed with glycerine diboric dressing instead. The difficulty of dealing adequately with a struck area in this way, however, has proved too great, and in future the areas will be shorn off prior to dressing. It is possible that the method of dressing is responsible for a portion of the re-strikes. (See Table 4 below).

Nevertheless, the difference in the incidence of re-strikes between the "B" and the "C" untreated sub-groups is very marked.

TABLE 4.—SHEEP STRUCK ONCE AND MORE THAN ONCE. BREECH STRUCK SHEEP ONLY. (SEE TABLE 2).

Sub-group.	Number of Sheep Struck.						Total Breech Strikes.
	Once.	Twice.	3 Times	4 Times	5 Times	6 Times	
A treated	0	0	0	0	0	0	0
A untreated	0	0	0	0	0	0	0
B treated	0	0	0	0	0	0	0
C treated	5	3	1	0	0	0	14
B untreated	15	5	2	0	0	0	31
C untreated	33	26	27	7	2	1	210
Totals	53	34	30	7	2	1	255

3. Summary.

The results of the trial to date may be briefly summarized as follows:—

(*a*) The trial concerned 650 stud Merinos ewe weaners, 325 of which were treated. The operation aimed at the removal of the medial breech fold and of the lateral breech fold when considered desirable.

(*b*) Tail strikes and breech strikes were considered separately, there being also 24 strikes of doubtful origin. When these 24 were omitted from the breech strikes, there were over 12 sheep struck on the breech amongst the untreated sheep for every one struck amongst the treated. When these doubtful cases were included as breech strikes, the ratio was 8:1.

(*c*) Of the nine treated sheep which were struck, six were ineffectively treated.

4. Acknowledgments.

We would like to express our appreciation to Mr. Mules who undertook the task of operating on the treated sheep, and to Dr. Riches for his assistance in classifying the experimental group. We would also like to thank Mr. J. A. Campbell for making the sheep available to us, Mr. F. M. Mackeig, manager of "Dungalear," for his assistance, and Mr. W. Stephens, H.D.A., of "Dungalear" for keeping the strike records. The ever-willing co-operation of these gentlemen has been of the utmost value.

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Report on the Natural Enemies in Haiti of the Horn-Fly (*Lyperosia irritans*) and the Green Tomato Bug (*Nezara viridula*).

By J. G. Myers, Sc.D., M.Sc., F.R.E.S., F.Z.S.

In the year 1936, Dr. J. G. Myers offered to make a vist of some two months' duration to the Greater Antilles to engage in an intensive study of the parasites of *Lyperosia* and *Nezara*. He indicated at the time that it might be that, as the result of the work, information of value to Australia in connexion with the buffalo-fly (*Lyperosia exigua*) and the tomato bug (*Nezara*) might be obtained. The Council took advantage of the offer and commissioned Dr. Myers to make the studies on its behalf. He subsequently furnished a report which is published below.—Ed.

Summary.

1. There is considerable evidence that the horn-fly is largely controlled in Haiti by natural enemies, of which the most important are a Histerid beetle and an Anthomyiid larva, both predaceous on the larva.

2. The Histerid is recommended to the earnest consideration of the Australian entomologists, who are familiar with buffalo fly conditions, for introduction into Australia.

3. The green tomato bug is parasitized in Haiti in October-November by *Trichopoda* sp. at the rate of only 4.1 per cent. It is suggested that *Trichopoda pennipes* in Florida is a more efficient and promising parasite.

1. Introduction.

There is in the West Indies a very general and very considerable difference between the Greater and the Lesser Antilles in the incidence of most insect pests. If we except Puerto Rico as being transitional in this respect as it is in situation, the other larger West Indian islands, Cuba, Hispaniola, and Jamaica, certainly suffer markedly less from most insect pests than do the smaller islands. This tendency reaches its extreme in Haiti and Santo Domingo, which make up the large island of Hispaniola, the geographical centre of the West Indies, with the highest land mass and a very rich flora and fauna. To explain this state of affairs needs a closer analysis than I have been able to give it in eight years' field work in the islands and the adjacent mainland. Since there are few meteorological or other physical ecological factors and fewer historical, economic, or agronomic conditions, which do not recur in the immensely varied field of the Lesser Antilles, one is tempted to suggest that biological factors are the predominant ones. But the incomplete knowledge of island floras and the still greater lack of anything like complete faunal lists, especially in the Insecta, makes this very difficult to prove in any general way. In individual cases, notably in that of the small borer of sugar-cane (*Diatraea saccharalis*)—as an excellent example of an indigenous insect become a pest—I think it can be shown that biological factors are immensely the most important. We have tested the theory in this instance by transporting one of the Greater Antillean biological factors—the Tachinid, *Lixophaga diatraeae*—into the typical Lesser Antillean island of St. Kitts, with the result that the borer has now reached there something very like its status in Cuba.

There are thus good grounds for regarding the Greater Antilles, and especially Haiti and Santo Domingo, as a promising hunting-ground for natural enemies of insects which occur there and are pests or greater

pests elsewhere. This argument should apply even to introduced host insects, provided the insect in question has been there long enough for members of the rich indigenous entomological fauna to learn* to parasitize or otherwise attack it.

I arrived in Haiti on the 14th of October, 1936, and left on the 22nd of November. When I arrived, the rainy season at Port-au-Prince was in full swing. The last heavy rains fell in the final days of October, and by the time I left dry season conditions looked as though they had endured several months, and the roadside vegetation was smothered in dust. Also the horn-fly was becoming much scarcer. I thus spent about six weeks in the field in Haiti and another week working up my material and preparing my report at the Imperial College of Tropical Agriculture in Trinidad. The season was probably the best that could have been chosen for investigating the horn-fly, but it was less favorable for the study of the green tomato-bug, eggs being practically unprocurable and egg-parasites thus impossible to find.

It was necessary, seeing that time was limited, to study infestations of both pests under different ecological conditions and, as it happened, in rather widely separated localities, at the same time, and this involved considerable travelling every day.

All the insect material collected, studied, and referred to in the report has been deposited with the Director of the Imperial Institute of Entomology for determination, with the request to forward it to the Commonwealth Entomologist.

The present inquiry affords an instance of the desirability, in any biological control investigation, of sending an entomologist rather than depending on what I have called the postal system of biological control, depending on information from local entomologists. For about a decade Haiti has employed an official agricultural entomologist, the first three having been Americans, while the present incumbent is American-trained. Inquiry from any of these officials would probably have elicited the information that the horn-fly, so far as they knew, did not occur in Haiti.

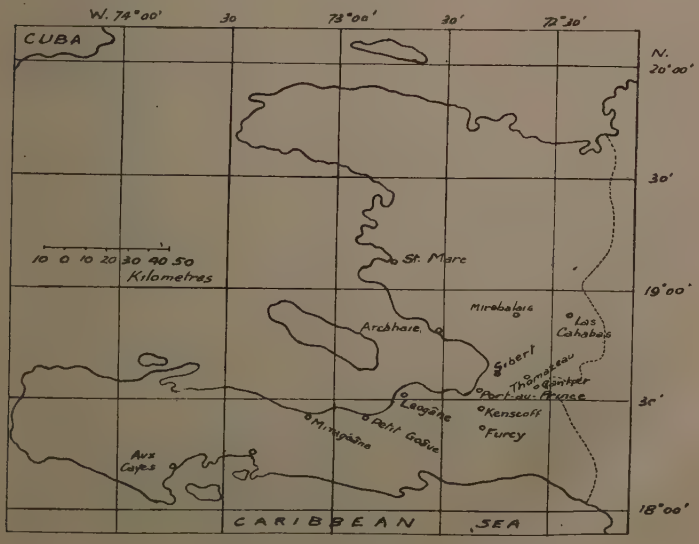
2. The Horn-Fly (*Lyperosia irritans*). Status and Distribution in Haiti.

Wolcott, in his book on the entomology of Haiti (1927), has a chapter (42) on the insects attacking stock, and mentions (p. 413) biting flies "dont la *Stomoxys calcitrans* . . . est la plus abondante et la plus desagreable . . .," but *Lyperosia* is not mentioned. The present entomologist, Mons. Audant, to whom I am indebted for every courtesy and help, did not know the insect. In my own previous visits to Haiti I had not looked for the horn-fly. In view of its importance as the most serious pest of stock in Puerto Rico, and considering the traffic between that island and Hispaniola, there seemed a good chance of finding the horn-fly there, too, and possibly under biological control. The present inquiry has shown the truth of the first possibility and the probability of the second. The horn-fly occurs in Haiti, but with a curious and restricted distribution which tallies with a theory of fairly recent introduction, by way of the neighbouring Republic of Santo Domingo. Concrete data for this theory are, however, lacking, as also was time to investigate the fly in Santo Domingo (known more formally as the

* I use the term "learn" deliberately and with full admission of its Lamarckian implication in this sense, since no other explanation seems to me plausible.

Dominican Republic) as well as in Haiti. *Stomoxys calcitrans* is abundant in Haiti and much more generally distributed than *Lyperosia*. and stock-owners have not differentiated between them. There is some evidence that "fly" has been worse during the last five or six years, and this may have coincided with the introduction of the horn-fly. Had it been as abundant as now, when I was here in 1931, I should certainly have heard complaints of it.

Lyperosia is said to have been introduced into the United States of America from Europe in 1886, and was probably transported from there into Puerto Rico, where it is a serious pest of long standing (see later). Santo Domingo, which is separated from Puerto Rico by only a narrow strait, breeds many cattle and has long exported them to Haiti. The main road from Santo Domingo to Port-au-Prince crosses the plain of Cul-de-Sac, and it is in this plain and in the southern part of the almost adjoining plain (to the north) of L'Arcahaie and in the mountains just behind Port-au-Prince that *Lyperosia* is found in Haiti, and, in the present inquiry, only there (see map). I believe only a theory of recent introduction can explain this very restricted distribution. As we shall see later, the area in question has *Lyperosia* at stations varying from sea-level to nearly 6,000 feet and from cactus-scrub to mountain rain-forest, with the difference in ecological conditions which such vegetational divergence indicates—while apparently similar stations further north, south, and west are without *Lyperosia*. Haiti is an exceedingly mountainous country. Its valleys tend easily to be ecological islands, and the spread of introduced organisms must necessarily be slow. In the case of the horn-fly, so straitly attached to its host, the absence of range cattle, save on a few exceptional properties, and the prevalence of tethering, must also delay its spread and restrict such spread largely to the medium of the roads, which are few. Thus the absence of the horn-fly from the very varied country between Port-au-Prince and Aux Cayes to the west and south (see map), and



Map of the Republic of Haiti.

between L'Arcahaie and the Artibonite to the north, seems to me explicable only on the theory that it has not yet had time to reach there.

Within the area of its present Haitian distribution as described, it seems certain that its local and seasonal abundance is affected by rainfall, but whether directly or indirectly is a matter for discussion. I am familiar with Professor Handschin's investigations in Java, which are held to indicate the direct and predominant effect of rainfall on *Lyperosia exigua.* On the other hand, in Puerto Rico, where the distribution, or at least the abundance of horn-fly, is also extremely patchy, Wolcott (1924) finds that *Lyperosia* is most abundant in the driest parts of the island, but only during the wet season, a biological factor reducing its numbers to a low level during the dry season—for then the small dung-beetles, *Aphodius lividus* and *Ataenius stercorator,* abound and eat all the fresh cow dung, so that the horn-fly larvae can scarcely live.*

Similar beetles occurred in fresh cow dung, in small numbers, at all the Haitian stations during my visit, but were certainly of practically no importance then. Reports have it that the "fly," which includes *Stomoxys,* is worse at the Cul-de-Sac stations during April and May. i.e., during the spring rainy season, and least in June, July, i.e., summer dry season. This is consonant with Javan and Puerto Rican experience as above, but is loosely attributed by stockmen to the fact that the north-east trades are steadier and more regular during the dry seasons, and these winds, owing to the lie of the mountains, sweep almost from the east down the Cul-de-Sac valley. For the single mountain station, which is much moister and cooler than the plains, I have no information on seasonal prevalence.

The four localities at which *Lyperosia* was studied in Haiti may be described as follows :—

1. *Sibert.*—On the Cul-de-Sac plain, this is an area of pastures which are used in rotation for the draught bullocks—fine quarter-bred Mysore animals imported from Santo Domingo—used by the Haytian American Sugar Company (Hasco). The rainfall of the Plaine du Cul-de-Sac is 800–1,000 mm. annually (Woodring, Brown, and Burbank), and that at Sibert is certainly nearer the first than the second figure (probably 850). The mean monthly temperatures (1909-1916) of Gantier, which is out on the plain of Cul-de-Sac, well south-east of Sibert, are, in degrees Centrigrade, January-December—24.0, 24.8, 25.4, 26.3, 27.3, 27.6, 27.9, 27.5, 27.1, 26.0, 24.6. It is probable that Sibert, for which I have no records, is similar in temperature. According to Woodring *et al.* (p. 582), the rainfall of Cul-de-Sac should suffice without irrigation for many crops, if the rains were regular and conveniently distributed, which they are not, while the high temperature renders conditions still more arid. The following are the average monthly rains for Thomazeau (east of Sibert and near Coustarde) for the period 1905-1919, in millimetres :—January, 8.5; February, 22.9; March, 34.9; April, 96.2; May, 144.3; June, 65.5; July, 64.7; August, 73.7; September, 125.3; October, 132.8; November, 81.0; December, 12.8. It will be seen that there are two rainy and two dry seasons.

* Incidentally, Wetmore (1916) finds that *Crotophaga ani,* one of the commonest birds in Puerto Rico, as in Haiti, and notable for its constant attendance on grazing stock, eats these beetles in considerable numbers (to the extent of 0.21 per cent. of its food).

Actually, the plain has been irrigated since French colonial days, and is at present the seat of the largest sugar-cane cultivations of Hasco, all under irrigation.

The above meteorological data, scrappy as they are, must serve to indicate the climate of the Plaine du Cul-de-Sac. The main ecological differences between my three stations on the plain are undoubtedly edaphic and vegetational. The pastures at Sibert consist chiefly of luxuriant guinea-grass (*Panicum maximum*), with very frequent shade of bayahonde or mezquite (*Prosopis juliflora*). This abundant but never heavy shade, which is well tolerated by the guinea-grass, seems biologically important. The incidence of horn-fly estimated on 29th October (i.e., in last days of wet season) was 50 to 150 per animal.

2. *Coustarde* (a few miles from Thomazeau, Plaine du Cul-de-Sac).—Here is a very different type of pasture and largely a salt flat (saline), bare in places, with patches of short turfy grasses, and occasional bayahonde (but nothing like the shade at Sibert). The chief grass is *z'herbe salé* (specimen taken for determination). There is also Bermuda grass (*Cynodon dactylon*) and a small *Chloris*. The salt grass is said to be very good for conditioning poor bullocks. The estimate of horn-fly incidence on 3rd November was 400 per beast. It is said to be much worse in full rainy season—so much so that the stockmen are accustomed to tie the animals up and spray them with "Flit," to which has been added a certain percentage of heavy oil to lengthen the effect.

3. *Near Damien,* Plaine du Cul-de-Sac.—Animals are tethered on patches of pasture (close-cropped turf of short grasses) between miscellaneous peasant crops, irrigated and in places even swampy; there is no shade. The incidence of horn-fly in late October is about 100 per beast.

4. *Kenscoff,* in the Morne la Selle massif, behind Port-au-Prince.—Altitude, 1,450 metres (4,757 feet); 31° C. maximum temperature, 4.5° C. minimum. The annual mean temperature of Furcy, over the ridge to the south and some 90 m. higher, is 18.4° C. The rainfall is probably at least 50 per cent. more than that of Port-au-Prince, and would thus reach 2,100 mm. But the climate at Kenscoff is much moister than this would indicate, owing to the prevalence of heavy mists which sometimes envelop the locality all day. The slopes have been largely deforested, and, save where planted in maize or other peasant crops, are chiefly in pasture, on which the animals are tethered. The grasses, clovers, and weeds are predominantly of European species, presumably introduced in French colonial days, and the northern effect is heightened by elder hedges and occasional thickets of blackberry, as well as by the low temperature. There is practically no shade, save that of the mountains themselves, the residual forest consisting either of dense patches of low mountain scrub (with *Begonia* and *Fuchsia*) or isolated Haitian pines (*Pinus occidentalis*) on the higher slopes and ridges.

Horn-fly occurs (at a rate of no more than 50 to 100 per beast) in the neighbourhood of Kenscoff up to an elevation of at least 5,700 feet. Above this, at 5,950 feet, is the saddle, which separates Kenscoff from the Furcy district (to the south). Just beyond and below the ridge, in the same kind of country, at 5,400 feet on the road to Furcy, only *Stomoxys* was found on the cattle, and I must assume that the saddle is the present southern limit of distribution for the horn-fly and probably a barrier.

It was only at Kenscoff that I saw the horn-fly clustered at the base of one or both horns, according to the habit which has given the insect its popular name. Marlatt (1910) says this habit is seen only when the insect is abundant, but in Haiti I observed it only here, where the fly was least common, and then usually in cool, misty weather or on chilly, shaded slopes, when it seemed that all the flies left the body of the host to cluster, motionless, in this position.

3. Natural Enemies of Horn-Fly.

At all the three lowland stations the undisturbed condition of cow dung and the scarcity of insect inhabitants of whatever kind were very remarkable. This is presumably a result of the absence of grazing mammals, and in fact of any large mammals, in prehistoric Haiti, at least in recent times, until the introduction of European stock. At Coustarde the dung was even less disturbed than elsewhere, and remained largely compact and whole till thoroughly desiccated and indurated. Dung-beetles, at the time of my visit, were rare not only in the three low-land stations but also at Kenscoff. The least rare were tiny Aphodiines, but even these were never abundant. So far as my experience goes, the competition of dung-beetles may be dismissed as entirely negligible in its effect on horn-fly in Haiti, but there remains the possibility that, as in Puerto Rico, they may become more abundant in the full dry season.

The dung at the three lowland stations thus remained in excellent condition for horn-fly breeding till it was actually too dry—and this took a long time in the shaded conditions at Sibert, especially during the rains. Under these circumstances it was surprising to find the larvae so very rare—so much so that it was at all times difficult to find enough for experiment. As food for the predaceous insects in the laboratory, I had often to use other Muscoid larvae from the same dung. The scarcity of horn-fly larvae and puparia makes the non-discovery of larval or pupal parasites of little significance. They would, perhaps, have been found under conditions of greater host-abundance early in the rains.

Dung-competitors and parasites being both insignificant, at least during the time of my visit, there remains the effect of predators, and this, in my opinion, is of very considerable importance in Haiti.

There follows a list, with field notes, of the predators, proved and suspected, and their distribution at the different stations.

1. *Medium Black Histerid* (*Hister coenosus*, Er.).—This occurred abundantly at Sibert, less so at Kenscoff, and was absent from Damien and Coustarde. It would seem, therefore, that the greater amount of shade at Sibert was in some way, direct or indirect, more favorable to it. The adult beetle lives in very fresh moist dung, which it tunnels in all parts, and in which it is one of the least scarce inhabitants. It is one of the most efficient predators of dung-feeding Muscoid larvae that I know. One was kept in captivity, in a small ointment tin with manure on sand, for over three weeks from 31st October to 22nd November, when it was killed as a specimen. Eight *Lyperosia* larvae were put with it on 31st October; on the 2nd November three had been eaten, and the rest had pupated. Three more were introduced, and were eaten by the 6th. Four larvae were then introduced and six puparia.

On 10th, four puparia were left and no larvae. On 19th, six miscellaneous Muscoid larvae from cow dung were put in. Next day all were eaten, save one, which had pupated. It is thus evident that puparia are but little attacked. Actually, the beetle is abundant in dung too fresh to support puparia.

Under the same conditions of captivity this Histerid lived six days without food. To test the possibility of transporting it in company, five were put in the same small tin on 11th November. On 18th one was dead and broken up—it was difficult to say whether it was eaten or not. The others were well, and buried separately in the sand beneath the dung. Another was added from the field. On the 19th all were well. On the 22nd two were alive and three dead (of which two were broken up). In the eleven days of the experiment they had no food, so this was a sociability test of the most rigorous kind.

A minute black and red Histerid was found in the dung at the same stages of the ecological succession, at Sibert and Coustarde. It was rare, and no observations were made on its habits.

2. *Anthomyiid* (*Limnophora* sp.).—At all three lowland stations, the commonest, or rather the least rare, Muscoid larva in fresh cow dung was that of a small grey Anthomyiid. It occurred also at Kenscoff, but was there less abundant than *Scatophaga*. It readily ate all other Muscoid larvae from cow dung at approximately the same stage of desiccation, including those of *Lyperosia irritans*. In one day 27 nearly full-grown Anthomyiid larvae accounted for fifteen much larger *Scatophaga* larvae (about half-grown) and four *Lyperosia*. A very small proportion of the puparia of this Anthomyiid were parasitized by a small black Pteromalid.

The larvae occurred in dung at the favorable stage for horn-fly larvae and the medium black Histerid beetle, and the latter ate them as readily as horn-fly larvae. They are very similar to horn-fly larvae, long and slender, but of the same tough leathery consistency as those of *Hydrotaea dentipes*, which has the same habits in Europe.

The adult fly formed part of the prey, at Kenscoff, of the *Scatophaga* adults so abundant there. It, the adult *Lyperosia* (momentarily at oviposition), and the *Scatophaga*, were the most abundant Muscoid flies on and about fresh cow dung.

3. *Scatophaga* sp. (Det. as *S. stercoraria*, L.).—Handschin (1934), among his final suggestions, mentions the possible study of *Scatophaga* as the larvae prey on other maggots in dung, and the adults on other adult flies. I was therefore interested to find a *Scatophaga* very similar to, if not identical with, *Scatophaga stercoraria* (I speak from memory) very abundant at fresh cow dung in the Kenscoff district. It did not occur at all in the lowlands, and may possibly have been introduced into the Haitian uplands in colonial times, with the many European weeds and other plants and the snail, *Helix aspersa*. I embarked on observations and experiments with high hope, since *S. stercoraria* is known to occur over a wide range, reaching the Canary Islands and South Africa (Cotterell); so that it was conceivable that it might establish itself in Australia, though the form in Haiti was restricted to the temperate and sub-tropical uplands.

With regard to the supposed predaceous habits of the larvae, I could find no evidence in the field or in cultures. Its occurrence in the field, wherever it did occur in a pat of cow dung, was in abundant pockets,

many larvae crowded together, and sometimes so numerous as to occupy a whole pat and finally reduce it to a mere framework of fibres. This is the habit, surely, of a dung-feeder and not of a predator. It was, moreover, far more abundant than any other maggot on which it could have fed. Time was insufficient to rear young larvae right through on any medium, but the later stages were reared to maturity on cow dung alone. Moreover, *Lyperosia* and other Muscoid larvae, when confined in a minority with *Scatophaga* larvae, were usually unharmed, and, when the Anthomyiid larvae previously described were used, they devoured the *Scatophaga* maggots. In the literature and abstracts available to me in Trinidad, I have been unable to find any other authority for Handschin's statement that these larvae are predatory. Unfortunately, Cotterell's authoritative paper on *Scatophaga stercoraria* could be consulted only in abstract.

The adult *Scatophaga* is abundant in the vicinity of very fresh cow dung, while the surface is still wet. It is, in fact, the second in the race to settle on dung just as it is dropped. The first is *Lyperosia* itself, the horn-fly resembling its congener, the buffalo-fly, in this respect. It descends in a swarm on to the warm surface for oviposition the moment the dung is dropped. It leaves the dung, however, after a few moments, and before the greatest concentration of *Scatophaga* has arrived—the horn-fly, being *on* the beast, having, as it were, a long start in the race.

Scatophaga captures other insects, especially flies, dislocates the neck, and sucks the carcass by the orifice thus made. Hewitt (1914) found that *S. stercoraria* prefers Muscoid flies and listed the following as prey: —*Musca domestica, Calliphora erythrocephala, Stomoxys calcitrans, Fannia canicularis, Pollenia rudis, Orthellia cornicina,* and *Bibio longipes.* Austen (1921), however, pointed out that it usually attacked much smaller flies, and was of very doubtful importance as an enemy of the larger Muscoids, while Cotterell found that the main prey in the field was *Borborus equinus.* Rabaud (1923) was apparently the first to emphasize that *Scatophaga* does not go in search of prey. It remains near the dung or on adjacent plants as a vantage point, and merely captures any suitable insect which passes it, including Orthoptera, Rhynchota, and Diptera. My own observations in Haiti abundantly confirm Austen, Cotterell, and Rabaud. It seems certain, from the very habit Rabaud describes, and from the very close association of both flies with freshly-dropped dung, that the horn-fly must occasionally be a victim; but, as mentioned above, most of the horn-flies have already left the dung before the *Scatophaga* have congregated and certainly before they have begun capturing other insects. The first concern of the female *Scatophaga* is apparently oviposition, and of the male, copulation. That neither sex actually searches for prey is confirmed by the following observation:—I watched a cow lying with its head only one yard from a fresh pat of cow dung on which, and on adjacent weedstalks, numerous *Scatophaga* were congregated and actively moving. During fifteen minutes, not one came near the cow, which had a cluster of *Lyperosia* on the horn. Flies killed by *Scatophaga* are dropped and can easily be found near, or on, the cow-pats and recognized by the dislocated head. In proportion to the numerous population of *Scatophaga*, the number of victims seemed always insignificant, and I believe it really to be so; and, of this number, *Lyperosia* can be only a small minority. I never actually saw it as a victim. The favorite prey was the small grey

Anthomyiid previously described, which is of the same size and build as the horn-fly. On one occasion a *Sarcophaga* (*S. ? capitata,* Ald.) was taken, if anything bulkier than *Scatophaga* itself.

In my opinion, at least under Haitian conditions, *Scatophaga* can be eliminated from consideration as a significant predator of *Lyperosia,* either as adult or larva. As larvae, *Scatophaga* may be of some slight importance as a dung-competitior—certainly more so than any other dung-feeding insect found at this season in Haiti. A number of pats were found so completely skeletonized, as it were, by this sole agency as to be quite unsuitable for the breeding of *Lyperosia.* Ordinarily, however, the *Scatophaga* in any one pat—and they were present only in occasional ones—were congregated together in one small moist part, leaving the bulk of the pat unaffected.

4. *Pyrophorus* sp.—Larvae of *Pyrophorus* were found in all instars in cow dung, the younger in fairly moist dung, which was suitable also for maggots of *Lyperosia.* Since these larvae are long-lived, the older instars were usually in old dry pats, quite beyond the stage of supporting even puparia of the horn-fly. Larvae of *Pyrophorus* occurred, always in small numbers, at all the stations except Damien, but were least scarce at Sibert. They are efficient but very general predators. One larva, less than a quarter-grown, kept under the same conditions as the Histerid, ate nine full-grown Lyperosia maggots in two days. But ten puparia, placed with it on a previous occasion, were untouched after four days, with no alternative food.

5. *Solenopsis geminata.*—Very occasionally at Coustarde, in the wetter parts of the field, fire-ants were in possession of cow pats at a suitable stage for *Lyperosia.* In such cases we found practically no other insects, and especially no Muscoid larvae in the dung. At the peasant pasture near Damien, which was somewhat swampy, this ant was in complete charge, tunnelling nearly all cow pats of the right age (or about it) for *Lyperosia* and frequently nesting in them. There was a very great scarcity of other insects. On the lower Amazon and Rio Negro I have frequently noticed the predilection of this or a closely-allied species for swampy grassland. Riverside settlements have actually been abandoned on account of its abundance.

One other insect associated with the horn-fly in fresh dung may be mentioned. It is a small Diapriid, probably a species of *Trichopria.* On very fresh wet cow dung at Kenscoff only, it was often present in swarms walking delicately over the surface. What appears to be the same species was reared from puparia of a rather large species of *Sarcophaga* breeding in moist horse dung. In cow dung it seems very probable that the host is *Scatophaga,* whose puparia resemble considerably those of the *Sarcophaga* both in size and form. In no instance, however, was it actually reared from this host.

To sum up, the most efficient predaceous enemy of the horn-fly in Haiti is undoubtedly the black Histerid, with the Anthomyiid larvae running it a close second and being more generally distributed.

How far these predators are responsible for the comparatively low incidence of the horn-fly is difficult to estimate without comparative studies elsewhere. Only at Coustarde—where the Histerid is apparently absent—does the pest ever reach economic proportions. What is needed is a comparison of the ecological conditions of the four Haitian stations

with those of localities in southern Puerto Rico and in the southern United States of America, where the horn-fly is a serious pest. Since, however, the range of climatic and other physical factors, from the semi-arid tropical lowlands at Sibert and Coustarde to the moist cool uplands of Kenscoff, is very great—much greater than that between Sibert and Coustarde, at the former of which the horn-fly is negligible as a pest, while at the latter it is at times serious—I am inclined to attribute very considerable importance to the biological factors and notably to the two chief predators. The Anthomyiid apparently plays the same role as *Hydrotaea australis* in Northern Australia (Mackerras, 1932), though, perhaps, more efficiently. The Histerid, however, would seem well worthy of consideration by the Australian entomologists for introduction into the Commonwealth. They will be able to judge, in conjunction with the meteorological and other data here presented, whether any large proportion of the buffalo-fly area in Northern Australia presents ecological conditions conceivably suitable. That the beetle is able to thrive in such diverse environments as those of Sibert and Kenscoff, described above, is proof of wide adaptability.

Its collection in large numbers, and transport to Australia, would be a matter of comparatively small difficulty or expense. Haiti is thickly populated, and the people are economically more depressed than anywhere else in the West Indies. The payment of a small sum for hand-collecting would immediately enroll large numbers of men, women, and children, and the amassing of a large shipment would only be a matter of days.

4. The Green Tomato Bug (*Nezara viridula*).

With an eye on Australian needs, I paid some attention to this insect in my previous work in the West Indies. I quote largely from my 1931 report (p. 1936):—In Florida it is said by Jones (1918), Drake (1920), and Watson (1929) to be heavily parasitized by a Tachinid fly, *Trichopoda pennipes,* which may in some localities (Watson) control and even exterminate it. Drake, who records a parasitism of from 10 to 80 per cent. by the same fly, reared also one specimen of *Trichopoda lanipes,* and observed further a parasitism of about 6 per cent. by the fly, *Sarcophaga sternodontis.* He found an occasional Chalcid egg-parasite, *Ooencyrtus* sp., while Miller (1928) records another, *Telenomus* (*Microphanurus*) *megacephalus,* which occurs also in Grenada and St. Vincent.

Wilson (1923) observed the green bug in St. Croix parasitized up to 93 per cent. by *Trichopoda pennipes.* In St. Vincent the insect is said to be well controlled by egg-parasites (Ballou), including *Habrolepoidea submetallica* (Harland).

In the Guianas this pest seems rare, and hardly less so in Trinidad, where the scanty material obtained yielded no parasites. More extensive series of adults and nymphs were collected in Nevis (from cotton), in St. Kitts (from okra), in Montserrat (from tomatoes and *Crotalaria*), and in Antigua (from cotton). Dissection of these showed the adults to be parasitized at the average rate of 8 per cent., by a Tachinid fly, *Trichopoda pilipes.*

The most efficient known parasite is obviously the Tachinid fly, *Trichopoda pennipes.* Drake found that a species of *Crotalaria* attracted these flies in Florida so that bugs feeding upon this plant were uniformly

more highly parasitized. It is perhaps significant that a large proportion of the green bugs dissected in Montserrat, where the rate of parasitism (9.4 per cent.) by *Trichopoda pilipes* was higher than in the other islands, were collected on *Crotalaria*.

Such was the position so far as previous researches indicated. It is to be noted that the parasite situation in the Greater Antilles was not precisely known. Wolcott has since written (1933, p. 598) that in Puerto Rico (presumably) "*Nezara* adults are heavily parasitized by a fly, *Trichopoda pennipes* F., the eggs of which are often to be noted on the underside of the bug. The maggots of the parasite, on hatching, burrow into the bug and feed on its interior, causing its death a few days later. Parasitization is heaviest during the winter, thus being of greatest benefit to the winter vegetable grower."

On the basis of this statement it was to be expected that Haitian conditions would at least approximate more closely to the Floridan than to the Lesser Antillean conditions, but the present inquiry has indicated that this is probably not the case.

Material of *Nezara viridula* was collected chiefly on okra (*Hibiscus esculentus*), cotton, and a species of bean (*Phaseolus lunatus*). Some 2,000 were dissected and many reared, and the average parasitism of the adults by a species of *Trichopoda* (det. as *T. pilipes*, F.) was 4.1 per cent.—thus comparable with that by *T. pilipes* in St. Kitts and Antigua, 3.0 to 5.9 per cent. It is possible, of course, that, as noticed by Wolcott in Puerto Rico, the rate of parasitism is higher early in the rains, but my collections were largely made before the rains had ceased.

The eggs of the parasite, tightly plastered on, are by no means confined to the underside of the host. On the contrary, they are more often on the dorsum, especially the pronotum. Though four or more may be fastened to one bug, it is rare to find more than one larva surviving in the abdomen of the host. One of the first effects of the developing parasite is apparently to inhibit the development of eggs. Many of the females dissected were swollen with maturing eggs, but these were never found in one which contained a Trichopoda larva. The full-fed maggot squeezes out between the segments of the host, in one case observed between venter and thorax, leaving no trace of an opening, and inside merely the ragged remnants of gut and fat-body. Pupation takes place almost immediately, and the pupal period, under lowland Haitian conditions in early November, last eleven to thirteen days.

Eggs of *Nezara* were scarcely to be found during my stay in Haiti. From dissections, and from report, it seemed that egg-laying would begin about mid-December. In spite of assiduous search, only some 100 eggs and egg-shells were found, and none of these were parasitized. The study of egg-parasites, if present in Haiti, had, therefore, to go by the board.

The rate of parasitism by this species of *Trichopoda* is obviously not encouraging. Unless it can be shown that it is much more prevalent at other seasons, one can only recommend *Trichopoda pennipes* from Florida as a much more efficient parasite.

5. Acknowledgments.

I am indebted, as always, to my old friend, Mons. André Chevallier, for help of every kind in Haiti. I must thank also, for much courtesy and assistance, Mons. Montfils, in charge of the Service National de la

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In Trinidad I am grateful to Sir Geoffrey Evans, Principal of the Imperial College of Tropical Agriculture, for granting me, on this visit, all my old facilities at the college.

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Apple Investigations in Tasmania: Miscellaneous Notes.*

8. The Influence of Carbon Dioxide Concentration on Brown Heart and Other Storage Disorders.

By W. M. Carne, F.L.S.† and D. Martin, B.Sc.†

This progress report embodies results obtained from experiments following those previously reported in 1935 (1). Three series of experiment were carried out:—

1. Continuous storage for eight weeks under low concentrations of CO_2, 1936 and 1937.
2. Pre-storage treatment with high concentrations of CO_2, 1936 and 1937.
3. CO_2 accumulation in the early part of the storage period, 1937.

1. Series (1). Continuous Storage.

As in the 1935 experiments, air-tight pulp tins (43 lb.) were tapped with glass tubes to enable air to be withdrawn from either top or bottom. In each tin, 25 apples of 2½-in. size were placed, occupying approximately one-quarter of the interior space. The circular set-in lids were held in place with solder and the joints sealed with wax. The carbon dioxide was allowed to accumulate until it reached a pre-determined level at 50°–60°F. (usually about 48 hours) and then held there, with the tins in cool store, by controlling the ventilation by means of the two tubes and by blowing in air daily. The CO_2 concentration was determined daily by means of the Orsat-Fischer apparatus. Fluctuation from the pre-determined level was about 1 to 2 per cent. The samples were drawn from the bottom of the tins, but tests showed no appreciable difference when it was drawn from the top. The samples at the separate concentrations were duplicated.

As a result of the provision of better storage conditions,‡ greater control of temperatures was possible in 1937 as shown below.

Storage Temperatures:

1936.	1937.
(*a*) 32–34 F.	(*a*) 32–34 F.
(*b*) 45–55 F.	(*b*) 37–39 F.
(*c*) 55–65 F.	(*c*) 43–45 F.

Varieties.

The fruit was picked from the same groups of trees as in 1935 on the dates shown in the following tables. (For an explanation of the abbreviations used in the tables, see the appendix; the figures given in the tables are the percentage of fruit affected in each case.)

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* Continued from Vol. 8, page 271.

† An officer of the Division of Plant Industry.

‡ A part of the Commonwealth Apple and Pear Grant was made available to provide cool chambers for this work.

Concentrations of CO_2 *(mean).*

The mean concentrations of CO_2 were:—

1936.—3 per cent., 6 per cent., 9 per cent., 12 per cent., 15 per cent.

1937.—3 per cent., 6 per cent., 9 per cent.

TABLE 1.—FRENCH CRAB.

Eight Weeks' Storage.

Picks.		25.2.36.		19.3.36.		Picks.	22.2.37.		8.3.37.		22.3.37.	
Mean Percentage CO_2.	Mean Temperature.	B/H.	A/P.	B/H.	A/P.	Mean Temperature.	B/H.	A/P.	B/H.	A/P.	B/H.	A/P.
3 ..	34 F.	0	0	0	0	33 F.	0	0	0	0	0	0
6 ..	..	2?	2?	0	0	..	2?	6	0	0	0	4
9 ..	..	0	8	0	0	..	2?	0	0	8	0	12
12 ..	..	4	20	0	8	..	..	..	..	..	..	..
15 ..	..	4	82	..	..	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0
3 ..	50 F.	0	0	0	0	38 F.	0	0	0	0	0	0
6 ..	..	0	0	0	0	..	0	0	0	0	0	0
9 ..	..	0	0	0	0	..	0	0	0	0	0	0
12 ..	..	0	0	0	0	..	..	..	..	..	..	..
15 ..	..	2	0	0	0	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0
3 ..	60 F.	0	0	0	0	44 F.	0	0	0	0	0	0
6 ..	..	0	0	0	0	..	0	0	0	0	0	0
9 ..	..	0	0	0	0	..	0	0	0	0	0	0
12 ..	..	4	0	0	0	..	..	..	..	..	..	..
15 ..	..	52	0	20	0	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0

TABLE 2.—JONATHAN.

Eight Weeks' Storage.

Picks.		9.3.36.	6.4.36.		Picks.	8.3.37.	22.3.37.	5.4.37.
Mean Percentage CO_2.	Mean Temperature.	B/H.	B/H.	J/S.	Mean Temperature.	B/H.	B/H.	B/H.
3 ..	34 F.	0	0	12	33 F.	0	0	0
6 ..	..	0	0	14	..	0	0	0
9 ..	..	0	0	15	..	0	0	0
12 ..	..	0	..	..	..	..	..	..
15 ..	..	0	..	..	..	..	..	..
Control ..	..	0	0	0	..	0	0	0
3 ..	50 F.	0	..	..	38 F.	0	0	0
6 ..	..	0	2	12	..	0	0	0
9 ..	..	0	..	..	..	8?	0	2?
12 ..	..	2?	12	8	..	..	..	..
15 ..	..	2?	36	12	..	..	..	..
Control ..	..	0	0	0	..	0	0	0
3 ..	60 F.	0	..	..	45 F.	0	0	0
6 ..	..	0	0	12	..	0	0	0
9 ..	..	0	..	..	..	0	2?	0
12 ..	..	8	10	12	..	..	..	..
15 ..	..	20	44	10	..	..	..	..
Control ..	..	0	0	0	..	0	0	0

Table 3.—S.T.P. A.

Eight Weeks' Storage.

Picks.		27.4.36.		18.5.36.		Picks.	19.4.37.	3.5.37.			17.5.37.		
Mean Percentage CO_2.	Mean Temperature.	B/H.	A/P.	B/H.	A/P.	Mean Temperature.	B/H.	B/H.	A/P.	L/S.	B/H.	A/P.	L/S.
3 ..	34 F.	0	0	2	0	33 F.	0	0	0	0	0	0	4
6 ..	..	0	0	..	..	..	4	0	0	0	16	0	6
9 ..	..	0	0	36	0	..	38	26	10	0	56	4	10
12 ..	..	0	0	67	0	..	..	..	..	..	..	..	..
15 ..	..	10	0	92	0	..	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0	0
3 ..	46 F.	..	..	..	..	38 F.	0	0	0	0	0	0	14
6 ..	..	12	0	12	0	..	0	2	0	0	0	0	16
9 ..	..	..	..	..	..	..	0	30	24	0	26	0	12
12 ..	..	44	0	60	0	..	..	..	..	..	..	..	..
15 ..	..	52	0	76	0	..	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0	0
3 ..	55 F.	..	..	..	..	44 F.	0	0	0	6	0	0	32
6 ..	..	36	0	32	0	..	0	0	0	8	2	0	38
9 ..	..	..	..	..	..	..	0	0	0	4	18	0	40
12 ..	..	44	0	60	0	..	..	..	..	..	..	..	..
15 ..	..	52	0	76	0	..	..	..	..	..	..	..	..
Control ..	..	0	0	0	0	..	0	0	0	0	0	0	0

Table 4.—S.T.P. B.

Eight Weeks' Storage.

Picks.		4.5.36.	25.5.36.		Picks.	3.5.37.			17.5.37.			31.5.37.		
Mean Percentage CO_2.	Mean Temperature.	B/H.	B/H.	Sd.	Mean Temperature.	B/H.	A/P.	L/S.	B/H.	A/P.	L/S.	B/H.	A/P.	L/S.
3 ..	34 F.	0	14	32	33 F.	0	0	2	0	0	4	8	4	0
6 ..	..	0	..	..	..	31	0	0	8	0	0	36	10	0
9 ..	..	20	80	28	..	56	20	0	58	0	2	92	24	0
12 ..	..	88	100	0	..	..	..	..	..	..	..	..	..	..
15 ..	..	98	100	0	..	..	..	..	..	..	..	..	..	..
Control ..	..	0	0	55	..	0	0	0	0	0	0	0	0	0
3 ..	45 F.	..	..	..	38 F.	0	0	0	0	0	12	0	0	4
6 ..	..	20	60	32	..	0	0	0	2	0	12	14	4	10
9 ..	..	..	..	..	..	0	0	12	18	0	6	28	8	10
12 ..	..	68	92	32	..	..	..	..	..	..	..	..	..	..
15 ..	..	96	100	37	..	..	..	..	..	..	..	..	..	..
Control ..	..	0	0	32	..	0	0	0	0	0	0	0	0	1
3 ..	55 F.	..	..	..	44 F.	0	0	14	4	0	36	21	0	62
6 ..	..	..	..	..	..	4?	0	19	8	0	30	49	0	51
9 ..	..	68	56	4	..	2?	0	12	24	0	28	49	0	54
12 ..	..	100	100	0	..	..	..	..	..	..	..	..	..	..
15 ..	..	100	100	0	..	..	..	..	..	..	..	..	..	..
Control ..	..	0	0	13	..	0	0	0	0	0	0	19*	0	5

* Vascular Breakdown.

(1) The results do not show any difference in susceptiblity to brown heart in the fruit from the same trees in 1936 and 1937.

(2) Brown heart liability increased with maturity.

(3) The order of susceptibilty to brown heart in the different varieties was the same in both years. Sturmer A and Sturmer B were liable, French Crab intermediate, and Jonathan resistant.

(4) Results in Tables 1 to 4 were obtained after three weeks in air; some fruits cut immediately *ex* store showed symptoms.

(5) Susceptibility to alcoholic poisoning was in the same order as brown heart in 1936 and 1937. The incidence was greatest at low storage temperatures.

(6) Jonathan spot was present in Jonathans in 1936, but not in 1937. No correlation with temperature or CO_2 concentration was noted, but it did not occur in the fruit stored in air.

(7) Late scald occurred in Sturmer B in 1936, tending to be developed in air more than at the several concentrations of CO_2. It was also greatest at the lowest temperatures and least at the highest in the controls.

(8) Lenticel scald occurred in 1937 in Sturmer A and B in the several concentrations of CO_2 and slightly in air, and was greater at higher than lower temperatures.

(9) Breakdown did not develop in 1936 and 1937.

2. Series (2). Pre-storage CO_2 Treatment.

A sample of 75 fruits was placed in a 43-lb. pulp tin, and the concentration of CO_2 in the atmosphere in the tin was raised to between 50 and 60 per cent. by passing in CO_2. The tin was then sealed and held for 36 hours at room temperature (55°F.). During this time the concentration fell to from 35 to 45 per cent., probably by exchange with the internal atmosphere of the fruit. This with a similar quantity as a control was stored in air for fifteen weeks at 32°–34°F. followed by three weeks at room temperature, after which both were cut and examined for storage disorders.

The object of this experiment was to confirm results obtained in the United States of America in relation to breakdown and deep scald (2) using Tasmanian fruit.

Varieties.

Jonathan and S.T.P. A. were from the same groups of trees as for the continuous storage experiments; in addition S.P.M. and C.O.P. were from the same orchard, while S.T.P. C. came from another orchard.

Results.—The results are shown in Tables 5 to 9.

TABLE 5.—JONATHAN.

Picks.	9.3.36.	6.4.36.	8.3.37.		22.3.37.		5.4.37.		19.4.37.		
	J/S.	J/S.	J/S.	A/P?.	J/S.	A/P?.	J/S.	A/P?.	J/S.	A. P?.	L/S.
Treated ..	8	19	0	15	0	17	0	12	0	0	18
Control ..	3	11	0	0	0	0	0	0	0	0	3

TABLE 6.—S.T.P. A.

Picks.	27.4.36.	18.5.36.	19.4.37.	3.5.37.		17.5.37.		
	B/H.	B/H.	B/H.	B/H.	A/P?.	B/H.	V/B.	B/D.
Treated ..	4	45	0	0	7	0	20	9
Control ..	0	0	0	0	0	0	14	7

TABLE 7.—S.T.P. C.

Picks.	23.4.36.	7.5.36.			19.4.37.	3.5.37.	17.5.37.		
	B/H.	Pit.	B/D.	A/P?.	Pit.	Pit.	V/B.	B/D.	L/S.
Treated ..	23	6	0	9	0	0	14	0	0
Control ..	0	2	0	0	2	0	15	1	27

TABLE 8.—C.O.P. A.

Picks.	9.3.36.		24.2.37.			15.3.37.		22.3.37.		5.4.37.	
	Pit.	B/D.	Pit.	B/D.	A/P?.	Pit.	B/D.	Pit.	B/D.	Pit.	B/D.
Treated ..	63	15	58	9	26	91	88	30	65	17	73
Control	69	6	71	4	0	78	60	30	65	24	71

TABLE 9.—S.P.M. A.

Picks.	31.3.36.		14.4.36.		22.3.37.		5.4.37.		19.4.37.	
	S/S.	B/D.	S/S.	B/D.	S/S.	B/D.	S/S.	B/D.	S/S.	B/D.
Treated ..	6	0	10	0	0	0	39	4	8	11
Control ..	3	0	10	7	0	0	17	0	3	19

Pre-storage treatment with high concentrations of CO_2 did not reduce the incidence of breakdown or other disorders in 1936 and 1937. On the other hand the concentrations used apparently increased Jonathan spot in Jonathans when the liability was present as in 1936. They resulted in A/P? in Sturmer, Jonathan and Cox and brown heart in Sturmer.

It apparently induced lenticel scald in Jonathan and reduced it in Sturmer C.

Breakdown was increased in the earlier picks of Cox.

Scarlet spot of Scarlet apples was apparently increased, but not breakdown.

3. Series (3). Carbon Dioxide Accumulation and Brown Heart Causation in Unventilated Storage Conditions.

Arising out of observations, made by the senior author, of Australian fruit with brown heart in England during 1936, experiments were designed to provide some data on the following points:—

(*a*) The accumulation of CO_2 in confined spaces during a period of a few days.

(*b*) The incidence of brown heart in relation to the accumulation of CO_2 found in (*a*).

(*c*) The time of exposure to non-ventilated conditions to cause brown heart and the time taken for symptoms to develop.

The following experiments were made using the variety Sturmer Pippin which is known to be one of the most liable. The fruit was taken from the same group of trees in Plot A as used in continuous storage experiments, Series 1.

Experiment 1.

Picks of 1,120 fruits on—

1. 12th April, 1937.
2. 26th April, 1937.
3. 10th May, 1937.
4. 24th May, 1937.

Portion (*a*).—560 fruits, held at 55°F. for seven days, then sealed in 43-lb. pulp tins (70 fruit per tin which was then more than three-quarters full) and stored at 43°–45°F. For picks 1 and 2 the tins were removed in pairs after 24, 48, 72, and 96 hours, the concentration of CO_2 measured, and the fruit removed to air at 37°–39°F. Of the lots of 140 fruits so removed, samples of 35 were cut after 0, 2, 4, and 6 days at 38°F.

When no brown heart appeared with this treatment in picks 1 and 2, picks 3 and 4 were removed in pairs of tins after 48, 96, 144, and 196 hours at 43°–45°F., the concentration of CO_2 measured, and the fruit removed to air at 37°–39°F. and of the lots of 140 fruits so removed, samples of 35 were cut after 0, 1, 2, 6 days.

Portion (*b*).—560 fruits held at 38°F. for seven days, then sealed in tins (70 fruit per tin) and stored at 37°–39°F. then treated as above.

The results are shown in Figs. 1, 2, 3, and 4, and Table 10.

Fig. 1 shows the rate of accumulation of CO_2 for the four picks treated as in Portion (*a*).

Fig. 2 shows the rate of accumulation of CO_2 for the four picks treated as in Portion (*b*).

Fig. 3 shows the development of brown heart for the four picks treated as in Portion (*a*).

Fig. 4 shows the development of brown heart for the four picks treated as in Portion (*b*).

Table 10 shows the rate of development of brown heart symptoms after exposure to gas conditions for periods up to eight days.

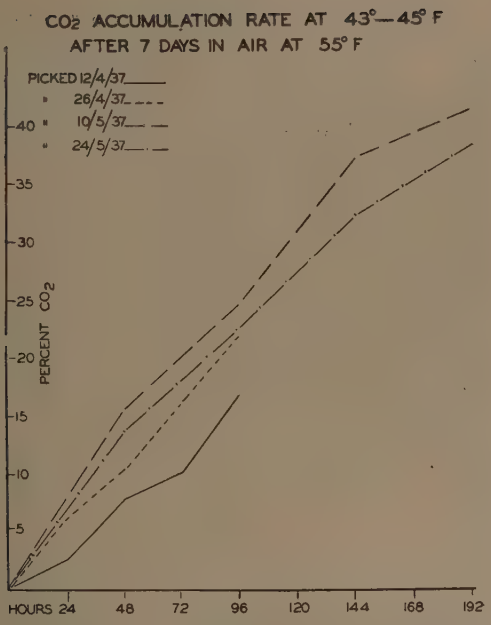
CO2 ACCUMULATION RATE AT 43°—45° F
AFTER 7 DAYS IN AIR AT 55° F
PICKED 12/4/37
" 26/4/37
" 10/5/37
" 24/5/37
PERCENT CO2
40
35
30
25
20
15
10
5
HOURS 24 48 72 96 120 144 168 192

FIG. 1.

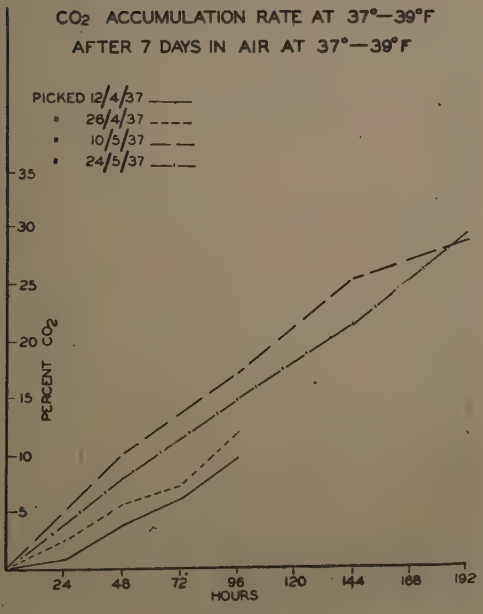
CO2 ACCUMULATION RATE AT 37°—39°F
AFTER 7 DAYS IN AIR AT 37°—39°F
PICKED 12/4/37
" 26/4/37
" 10/5/37
" 24/5/37
PERCENT CO2
35
30
25
20
15
10
5
24 48 72 96 120 144 168 192
HOURS

FIG. 2.

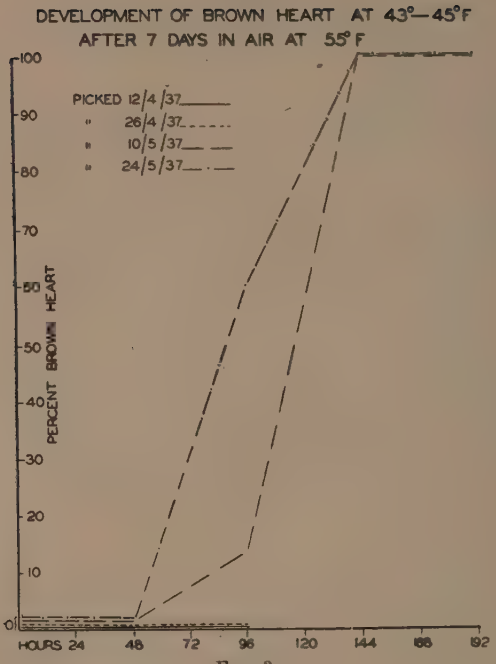
DEVELOPMENT OF BROWN HEART AT 43°—45° F
AFTER 7 DAYS IN AIR AT 55° F
PICKED 12/4/37
" 26/4/37
" 10/5/37
" 24/5/37
PERCENT BROWN HEART
100
90
80
70
60
50
40
30
20
10
0
HOURS 24 48 72 96 120 144 168 192

FIG. 3.

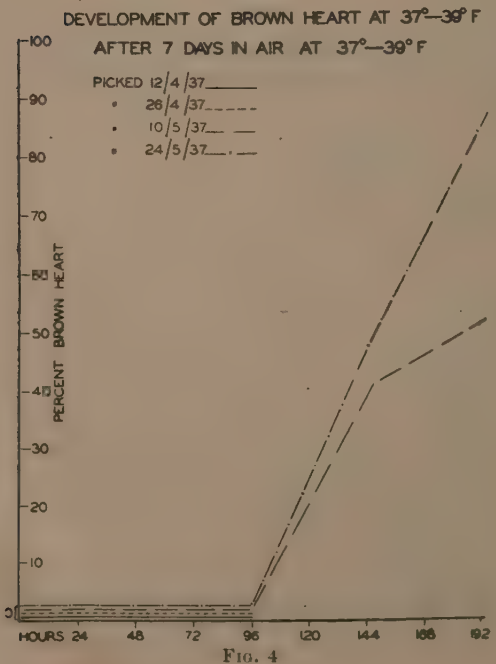
DEVELOPMENT OF BROWN HEART AT 37°—39° F
AFTER 7 DAYS IN AIR AT 37°—39° F
PICKED 12/4/37
" 26/4/37
" 10/5/37
" 24/5/37
PERCENT BROWN HEART
100
90
80
70
60
50
40
30
20
10
0
HOURS 24 48 72 96 120 144 168 192

FIG. 4

TABLE 10.—PICK 4.

Portion (*a*) CO_2 Accumulating at 44 F.				Portion (*b*) CO_2 Accumulating at 38 F.			
Hours in CO_2.	Final Percentage CO_2.	Days in Air.	Percentage Brown Heart.	Hours in CO_2.	Final Percentage CO_2.	Days in Air.	Percentage Brown Heart.
96	22	0	0	96	15	0	0
		1	0			1	0
		2	20			2	0
		6	63			6	0
144	32	0	0	144	21	0	0
		1	31			1	0
		2	97			2	20
		6	100			6	49
196	38	0	0	192	28	0	1
		1	80			1	40
		2	100			2	83
		6	100			6	94

Experiment 2.—*Rate of Development of Brown Heart Symptoms after Exposure to Non-ventilated Conditions for* 21 *Days.*

Seventy-five fruits from the same group of trees as used in the other experiments were sealed in a 43-lb. pulp tin on 20th May, 1937. The respired CO_2 was allowed to accumulate at 50°F. The concentration was read daily, and the pressure released. Fig. 5 shows the rate of accumulation of CO_2. On 11th June, 1937, when the concentration of CO_2 had reached 86 per cent., the fruit was removed to air and 35

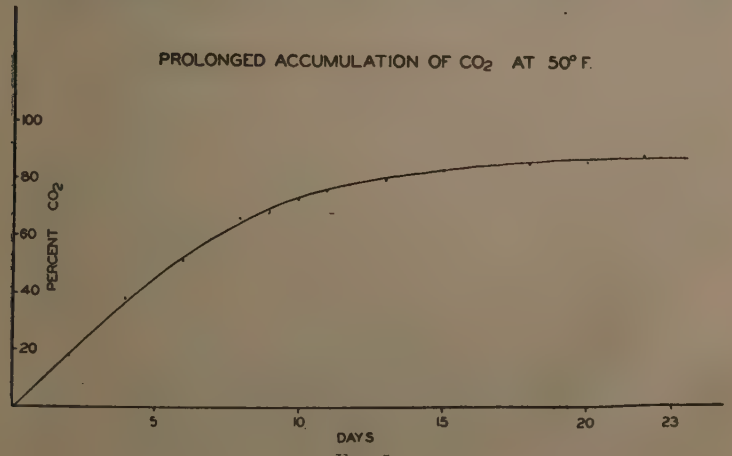

FIG. 5.

fruits cut; these showed no brown heart. On 14th June, 1937, the remaining 40 fruits were cut; all of these were severely affected with brown heart.

Experiment 3.—*Slow Reduction of* CO_2 *Concentration compared with Direct Removal to Air in Relation to Brown Heart Causation.*

On 20th August, 1937, two pulp tins containing 75 apples were sealed, and the respired CO_2 allowed to accumulate for five days when the concentration reached 28 per cent. From one tin the fruit was transferred directly to air, while in the other the concentration was allowed to fall gradually to 0 per cent. in three days. On 30th August, 1937, all fruit was cut and examined for brown heart. Fruit removed directly to air showed 43 per cent. brown heart while under the other treatment the fruit showed 100 per cent.

Experiment 4.—*The Effect of Exposure to Low Concentrations of* CO_2 *for Short Periods.*

In this experiment S.T.P. was used from the same group of trees as in Experiment 1, and picked on the same dates.

The original project was (using 60 fruits per tin which was then about three-quarters full) to allow the respired CO_2 to accumulate to 3 per cent., 6 per cent., and 9 per cent., and to hold at these levels at four days at 33°F., 38°F., 44°F., and 55°F. However, when no brown heart appeared in Pick 1 or Pick 2 even after thirteen days at 3 per cent. or eleven days at 6 per cent., it was decided to increase the concentrations to 6 per cent., 9 per cent., and 12 per cent. The 9 per cent. lots were removed after four days to preserve continuity through all picks. When no brown heart appeared in Pick 3 except in the 12 per cent. lot after ten days, it was decided to increase the concentrations still further to 9 per cent., 12 per cent., and 15 per cent., removing the 9 per cent. lot after four days, and the others after seven days.

After four days at 9 per cent. at the temperatures used, no brown heart appeared in any of the four picks.

TABLE 11.—PERCENTAGE BROWN HEART IN PICK 3.

Temperature.	Treatment.	Percentage Brown Heart.
33° F.	9 days at 6 per cent.	Nil
	6 days at 12 per cent.	Nil
38° F.	9 days at 6 per cent.	Nil
	7 days at 12 per cent.	Nil
43° F.	9 days at 6 per cent.	Nil
	9 days at 12 per cent.	8
55° F.	9 days at 6 per cent.	Nil
	9 days at 12 per cent.	4

TABLE 12.—PERCENTAGE BROWN HEART IN PICK 4.

Temperature.	Storage Conditions.	Total Brown Heart.	Severe Brown Heart.
		%	%
33° F.	7 days at 12 per cent. CO_2 ..	7	0
	7 days at 15 per cent. CO_2 ..	45	10
38° F.	7 days at 12 per cent. CO_2 ..	15	0
	7 days at 15 per cent. CO_2 ..	58	42
43° F.	7 days at 12 per cent. CO_2 ..	10	0
	7 days at 15 per cent. CO_2 ..	35	10
55° F.	7 days at 12 per cent. CO_2 ..	7	0
	7 days at 15 per cent. CO_2 ..	22	16

The following observations are made as a result of these experiments:—

(1) The rate of CO_2 accumulation increased with maturity up to the third pick, but declined in the fourth pick.

(2) The liability of the fruit to brown heart increased with maturity.

(3) A concentration of about 12 per cent. CO_2 was the lowest causing brown heart in Sturmer picked in May for unventilated storage periods of seven days.

(4) Experiment 1, which roughly reproduced the conditions experienced by pre-cooled and non-pre-cooled fruit in unventilated cool storage, showed a reduction in CO_2 accumulation, and the rate of incidence of brown heart in the former as compared with the latter. In May picks of Sturmers, CO_2 accumulated sufficiently in five days to cause brown heart in the pre-cooled fruit as compared with only three days in the non-pre-cooled.

(5) The relation of the incidence of brown heart to temperature at given concentrations was not shown by these experiments.

(6) Rapid, as opposed to slow, reduction of the concentration of CO_2 decreased the incidence of brown heart.

(7) Practically no symptoms of brown heart developed in the CO_2 concentrations causing brown heart after unventilated storage up to 23 days, even when the concentration reached 86 per cent. At least 48 hours in air at room temperatures were necessary to allow full development of symptoms

4. Conclusions.

Taken in conjunction with the results obtained in 1934 and 1935, the following tentative conclusions appear justified in relation to brown heart and alcoholic poisoning, &c.

Brown Heart.—Sturmer is very susceptible, French Crab susceptible and Jonathan relatively resistant.

The danger of CO_2 concentrations is related to the maturity of the fruit and the period of exposure.

Susceptibility increases with the maturity of the fruit.

A concentration of 3 per cent. CO_2 has caused some brown heart in May picked Sturmers held at 32°–34°F. for eight weeks, while 12 per cent. has caused injury in seven days.

At 38° and 44°F. brown heart has been caused in May picked Sturmers in three and five days respectively when held in unventilated storage.

CO_2 production of Sturmers increases up to a stage of maturity and then declines.

Delay between picking and cooling Sturmers may increase or reduce CO_2 production by causing the fruit to become more forward, but at the same time it increases the liability of the fruit to brown heart.

Cooling before unventilated storage reduces the rate of CO_2 production and delays the onset of brown heart.

When CO_2 accumulation has reached a dangerous point, rapid ventilation is superior to slow.

Brown heart symptoms develop slowly in CO_2 concentrations. Though they eventually develop in long storage, they are rare or absent in affected fruit after one to three weeks until it has been exposed to air. At least 48 hours in air at 50°–60°F. is necessary for full development after such short storage.

Alcoholic Poisoning.

The susceptibility of Sturmer, French Crab, and Jonathan is in the same order as for brown heart.

Susceptibility is generally less to alcoholic poisoning than to brown heart. These disorders may occur together or in different fruits.

Susceptibility increases with CO_2 concentration, but declines with increase in temperature. It occurs at temperatures under 38°F.

The following apparent associations are based on experiments in 1936 and 1937 only:—

Breakdown.—In the general absence of breakdown the effect of CO_2 concentrations in the storage air has not been noted. Pre-storage treatment with high concentrations of CO_2 has not reduced breakdown, and has apparently increased it in early picks of C.O.P.

Jonathan and Scarlet Spot.—CO_2 in the storage air apparently increased Jonathan spot. Pre-storage treatment with high concentrations of CO_2 apparently had the same effect on Jonathan, and increased spotting in Scarlet.

Lenticel Scald.—CO_2 in the storage air apparently increased lenticel scald in Sturmer. It also increased with the temperature of storage.

Late Scald.—This occurred on S.T.P. B. 1936, when it apparently decreased with an increase in storage temperature, but was not affected by CO_2 in the storage air.

The results reported here are progress results only.

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6. West, C.—Brit. Assn. Refrig. xxviii., 2, 1932.

7. Carne, W. M., and Martin, D.—This *Journal* 8: 1, 1935.

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Appendix.

Explanation of Abbreviations used in all Tables in this Report.

B/H. *Brown Heart.*—A disorder associated with excess of CO_2 (3, 4, 5, 6). In the continuous storage experiments this disorder took a form in which the lesions occurred mainly in the core region, especially at the lower concentration of CO_2, extending to the cortex in severe cases. In the pre-storage treatments, small lenticular cavities developed in the core and cortex. Accumulation of CO_2 in storage tests lasting up to eight days resulted in the development of numerous, rounded, dark, injected lesions sharply defined from the surrounding sound tissue and occurring mainly in the outer cortex.

A/P. *Alcoholic Poisoning.*—Such of this disorder as did appear was very similar to that previously described (7).

A/P?. A disorder, probably a form of alcoholic poisoning, occurring in the fruit receiving pre-storage CO_2 treatment. It appeared as shining, black, rounded, sunken depressions on the surface of the fruit. The damage was not extensive, and the individual lesions not more than 1 cm. in diameter or more than 0.3 cm. deep. The lesions were not confined to any particular part of the surface of the fruit.

J/S. *Jonathan Spot.*—Similar to that previously described (8).

S/S. *Scarlet Spot.*—Resembling Jonathan Spot.

V/B. *Vascular Breakdown* (*including Fleck*).—A sensecent breakdown characterized by the browning of the flesh vasculars and adjacent tissues. Typically a disorder of late-picked fruit held too long in cool store. Frequently mistaken for bitter pit and possibly for brown heart.

One form has been distinguished by the authors as "fleck." This form has occurred regularly in their experiments with late picked C.O.P., especially when stored at temperatures high enough to check the onset of low temperature breakdown. The symptoms are a browning of the vasculars of the flesh which, when cut, appears flecked with brown. In "fleck" the lesions are small in section. It may be followed by a general indefinite browning of the mealy flesh.

Another form, more characteristic of French Crab and S.T.P., though it does occasionally occur in C.O.P., shows fewer larger and usually deeper-seated lesions. Usually these lesions extend radially from the main vasculars of the core line. They are much larger, up to 0.5 cm. in diameter, than the fleck lesions and may dry out forming irregular cavities.

Vascular breakdown has been found mainly in varieties subject normally to low temperature breakdown. It usually appears in samples which for some reason are relatively resistant to, or which are stored under conditions tending to inhibit, low temperature breakdown. For instance, late picked C.O.P. stored at 38°–40°F. may develop vascular breakdown when similar fruit held at 32°–34°F. develops low temperature breakdown. Also in seasons when liability to low temperature breakdown is low, vascular breakdown may develop at relatively low temperatures.

Vascular breakdown may develop in storage periods as short as eight weeks. It may be confused with bitter pit, especially as the lesions may show through the unaffected skin, suggesting external pitting in its initial stages. With a reasonable range of specimens it may be distinguished from bitter pit by the absence of surface lesions, the absence of starch in the flesh lesions and the merging of vascular breakdown and flesh breakdown without the intervening zone or halo of unaffected tissue which surrounds a pit lesion associated with breakdown.

It may be distinguished from brown heart by the absence of a defined flesh breakdown and the characteristic lenticular cavities common in that disorder. Further, vascular breakdown is not uncommon in late picked fruit of certain varieties in Tasmanian land stores, while brown heart has never been recorded under such conditions.

Sd. *Late Scald.*—A general irregular indefinite browning of the skin of overstored fruit. Occurs in both cool and common storage on non-flushed varieties. At normal air temperatures the colour tends to darken, and the affected areas to become defined and slightly sunken. The lenticels involved are browned, and may be surrounded by a narrow ring of non-discoloured skin.

The Tasmanian varieties most affected, in the authors' experience, have been Crow Egg, Alfriston, Cleopatra, and Sturmer. In the first two it has frequently been found developing in, and from, the stem depression, otherwise any part of the surface may be affected.

L/S. *Lenticel Scald or Spot.*—A browning of the lenticels in the centre of small, brown, finally depressed, spots. The spots are usually regularly rounded and smoothly depressed, ranging from pin points to a few millimetres in diameter, or if confluent up to 1 cm. In one form, found in non-flushed varieties, the brown lenticels may be surrounded by an unaffected area in turn surrounded with a brown margin. This has been confused with Jonathan Spot. Lenticel scald is a disorder of over-mature fruit due to late picking and over-long storage. The spots are very subject to fungal infection resulting in spot rotting. Many varieties are affected, including Jonathan, Cleopatra, S.T.P., Rome Beauty, Democrat, &c.

D/S. *Deep or Soft Scald*

B/D. *General breakdown* of the low temperature type (9).

Varieties.—*F.C.*—French Crab; *S.T.P.*—Sturmer Pippin; *Jon.*—Jonathan; *C.O.P.*—Cox's Orange Pippin; *S.P.M.*—Scarlet Pearmain (Scarlet Nonpareil).

Studies of Growth and Fruit Bud Formation.

VI. A Summary of Observations During the Seasons 1930/31 to 1934/35.

*By C. Barnard, D.Sc.**

Summary.

The time of fruit bud formation has been determined for a number of varieties of pome and stone fruits in some of the more important fruit growing centres of Victoria, South Australia, Western Australia, and Tasmania.

In apples, the fruit buds are formed during the late December and early January, while in stone fruits differentiation is generally later. An important factor causing variation in the time of differentiation from season to season in any one variety appears to be the amount of fruit carried by the trees. Heavy crops are associated with an early cessation of shoot growth and an early differentiation of the fruit buds; differences in seasonal conditions do not affect the time of differentiation to any appreciable extent, though climatic conditions unfavorable for vegetative growth probably tend to induce early fruit bud formation.

The rate of development of the buds after differentiation is very much the same for any one variety during different seasons. Any factor which tends to depress shoot growth such as drought or the presence of a heavy crop retards development.

1. Introduction.

During the seasons 1930-31 to 1934-35, studies were made of shoot growth and fruit bud development in a number of varieties of fruit trees growing under Australian conditions. In previous communications, the results of some of these studies have been recorded, and information has been given concerning the grape (1, 2), orange (3), apple (4, 5), pear (6), plum (7), prune (7), peach (8), and apricot (8). Investigations relating to the grape dealt with observations made over a number of seasons, those dealing with the apple in South Australia (5) covered two seasons, but the results so far published for other fruits are confined to the records of a single season. The purpose of the present article is to summarize briefly additional data concerning fruit bud differentiation and development in pome and stone fruits. These data permit comparisons to be made between the same variety of fruit during different seasons in the one locality and during the same season in different localities. Records are presented of three seasons' observations on the apple, pear, plum, peach, apricot, and prune in Victoria, and the apple in South Australia; of two seasons for the apple in Tasmania and the Federal Capital Territory, and of one season for apples in Western Australia.

* An officer of the Council's Division of Plant Industry, Canberra.

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2. Materials and Methods.

A list of the varieties selected for study and of the districts in which the observations were made, is given in Tables 2 and 3.

(a) The Trees.

The sources of material for both pome and stone fruits from the Victorian districts were the same during 1931-32 and 1932-33 as previously reported for 1930-31 (4, 6, 7, 8). The apple trees from which the buds were collected in South Australia have also been previously described (5).

The Cox's Orange Pippin trees used in Tasmania were 22 years of age in 1932-33 and were grown on Crofton on seedling stock; the Cleopatra trees were 30 years old at the commencement of the period of observation and were growing directly on seedling stock. The buds of Cleopatra from Western Australia were sampled at random from the trees in two orchards, one in the Bridgetown district and one at Porongorups near Mt. Barker. In both cases the trees were approximately 25 years old and were growing on Northern Spy. The Jonathan buds from Canberra were obtained from twelve-year old trees on Northern Spy during 1930-31 and from older trees on the same type of stock during 1932-33.

(b) Sampling.

In Victoria, South Australia, and Tasmania, five trees of each variety were selected and at each collection three buds were taken from each tree. The composite samples of fifteen buds were duplicated. Samples were taken once a week until after differentiation had been observed, and thereafter at intervals of approximately three weeks throughout the season. In Western Australia and at Canberra, buds were sampled at random from trees in the selected orchards.

Terminal buds on spurs two years of age or older were examined in all apple varieties except Jonathan and Yates. For these two varieties, terminal buds on new spurs from two-year-old wood were selected. Both types of bud were examined from Jonathan, Cleopatra, Dunns, and Granny Smith apples in South Australia during 1932-33. In pears, the terminal buds of new spurs on two-year-old wood were selected in Victoria, but at Canberra the buds from older spurs were used. In the Grand Duke plum, buds from new spurs on two-year-old wood were taken, and in the Satsuma buds from spurs at least four years' old were selected. In the latter variety, axillary buds from the current season's growth were also examined during 1930-31. Both buds from old spurs and from axillary positions on the current season's shoots were examined in the case of the Burbank plum at Canberra. Axillary buds on current season's wood were used for the apricot and peach varieties and spur buds for the Prune d'Agen.

(c) Bud Examination and Record of Observations.

The dissection method (4) was used for preparing the buds for examination, at a magnification of from 50 to 100 diameters under a binocular microscope. For the purpose of recording results, the development of the bud was divided into a number of axillary stages* and

* A description of the structure and development of the fruit bud in each of the varieties dealt with here has been given previously (4, 6, 7, 8).

the number of buds coming within the limits of each stage was determined for each collection. In Table 1, an example is given in the record for buds from Dunns apple at Blackwood, South Australia, during the period December to March, 1932-33.

TABLE 1.—BUD DEVELOPMENT IN DUNNS APPLE, SOUTH AUSTRALIA, 1932-33.

Date of Collecton.	Stage of Development.*														Notes.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
30.11.32	12															
7.12.32	14															
14.12.32	12															
21.12.32	20	3														
28.12.32	3	3	5	2												
4.1.33	..		4	5												
11.1.33	..	1	1	1	4	3										
18.1.33	1						7†	3								†3 of these stage 7–8
25.1.33	..								2	3	7†					†3 of these stage 10–11
1.2.33	2									1	4	3†				†2 of these stage 11–12
15.2.33	..										4	6†				†4 of these stage 11–12
1.3.33	..											3†	6	1		†really stage 13–14
15.3.33	..												3	6		
29.3.33	..												2	6	2†	†really stage 14–15

*Stage 1, no differentiation; stage 2, first indication of differentiation, vegetative apex distinctly raised, enlarged and convex; stage 7, sepals of terminal flower differentiating; stage 11, petals arising in terminal flower; stage 12, stamens arising; stage 14, carpels appearing.

Of the thirteen buds examined from the collection made on 28th December, 1932, there were three undifferentiated, three at stage 2, five at stage 3, and two at stage 4. Thus the average development at this date was that represented by stage 3. By determining the average stage of development in each collection the development of the bud could be graphically represented and compared in different seasons and for different varieties. Further, though the period during which buds differentiated (stage 2 being the first detectable stage in differentiation) might extend over several weeks, it was possible to fix arbitarily a date at which most buds were differentiating. In the example given, the majority of the buds differentiated during the week 21st—28th of December, but the date 24th December, 1932, may be taken as the time of differentiation for purposes of comparison with other varieties. In some varieties the period of differentiation was more extended than shown in Dunns and also a greater range of stages were represented in any one collection. In the example, moreover, practically all buds examined were fruit buds. Where a large percentage of the buds in the collection were leaf buds, many more buds had to be examined to obtain a comparable number of observations for the fruit buds.

3. The Time of Differentiation of the Fruit Buds of Apples and Pears.

The dates of fruit bud differentiation, determined as described above, are given in Table 2 for the varieties of pome fruit examined during the four seasons 1930-1934.

From these data the times of differentiation in different varieties, seasons, and localities may be compared.

(a) In Different Seasons.

The time of differentiation in the same variety of apple in the one locality may vary somewhat from season to season, the greatest variation noted being fourteen days. There is some evidence to show that these differences are related to differences in the amount of fruit carried. In seasons when a heavy blossoming occurs and an "on" year crop is borne, few fruit buds are formed and they differentiate at an earlier date than the fruit buds formed during the "off" crop season. The more marked

TABLE 2.—TIME OF FRUIT BUD DIFFERENTIATION.*

Apples.

Variety.	Locality.	Season 1930-31.	Season 1931-32.	Season 1932-33.	Season 1933-34.	Season 1934-35.
Cleopatra ..	Harcourt, Vic. ..	14.12.30	27.12.31	..	..	..
,, ..	Blackwood, S.A. ..	..	..	24.12.32	13.12.33	20.12.34
,, ..	Bridgetown, W.A.	17.12.30	..	..	..	..
,, ..	Porongorups, W.A.	28.12.30	..	..	..	..
,, ..	Huonville, Tas. ..	..	..	6.1.33	29.12.33	..
Jonathan ..	Templestowe, Vic.	15.12.30	15.12.31	30.12.32	..	..
,, ..	Blackwood, S.A. ..	..	..	21.12.32	20.12.33	25.12.34
,, ..	Canberra, F.C.T. ..	13.12.30	..	24.12.32	..	..
Yates ..	Templestowe, Vic.	15.12.30	20.12.31	29.12.32	..	..
Dunns ..	Harcourt, Vic. ..	27.12.30	7.1.32	28.12.32	..	..
,, ..	Blackwood, S.A. ..	..	..	24.12.32 Circ.	..	30.12.34
Granny Smith	Beaconsfield, Vic. ..	..	..	1.1.33	..	..
,, ,,	Blackwood, S.A. ..	2.1.31 18.1.31	..	4.1.33	1.1.34	4.1.35
Delicious ..	Beaconsfield, Vic. ..	..	..	4.1.33	..	..
Cox's Orange Pippin	Huonville, Tas. ..	..	..	12.1.33	7.1.34	..
Rome Beauty	Templestowe, Vic.	9.1.31	15.1.32	17.1.33 After	..	..
,, ,,	Canberra, F.C.T. ..	..	..	22.1.33	..	..

Pears.

William bon Chretien Pear	Templestowe, Vic.	..	28.12.31 Circ.	28.12.32 Circ.	..	..
	Shepparton, Vic. ..	9.12.30	18.12.31	5.12.32 Circ.	..	..
	Canberra, F.C.T. ..	..	..	25.12.32	..	..

* Results for all varieties of apples except Jonathan and Yates are for terminal buds of spurs of two years of age or older. In Jonathan and Yates results are given for terminal buds on new spurs from two year old wood. Buds from new spurs underwent differentiation about three days earlier than those from old spurs in Jonathan and Dunns but no difference was observed between new and old spurs in Granny Smith and Cleopatra.

the alternation in cropping, the greater is the difference between the time of fruit bud formation in "on" and "off" seasons. The biennial bearing habit was most pronounced in Dunns followed in sequence by Delicious, Cleopatra, Granny Smith, Cox's Orange Pippin, Rome Beauty, Yates, and Jonathan.

The off crop seasons of the apple varieties listed in Table 2 were 1932-33 and 1934-35 for varieties from South Australia and Tasmania, and 1931-32 for those from the Harcourt and Beaconsfield districts of Victoria. The seasonal variation in crop was not so marked at Templestowe as in the other districts. Yates, Jonathan, and Rome Beauty formed an abundance of fruit buds during 1930-31 and 1931-32 but less during 1932-33. The 1930-31 season was an "on" crop year in Western Australia and also for the trees selected at Canberra.

The William Bon Chretien Pears at Shepparton in Victoria, differentiated some 9-13 days earlier in 1930-31 and 1932-33 than in 1931-32, though abundant fruit buds were formed in all three seasons.

(*b*) *In Different Localities.*

Insufficient data have been collected to permit of a comparison in detail of times of differentiation of the same fruit in different localities. It would seem, however, that there is very little difference in the time of differentiation at Blackwood in South Australia, the Templestowe district in Victoria, and Canberra. The Harcourt district may be several days, and Shepparton district about ten days, earlier, while Tasmania is some ten days later than Blackwood. About the same difference in the time of differentiation exists in the one variety in different localities as exists in the time of blossoming.

(*c*) *In Different Varieties.*

Having in mind the difference in the time of differentiation associated with "on" and "off" season crops and the difference due to location, an examination of the data in Table 1 shows that Cleopatra forms its fruit buds slightly earlier than any other of the varieties studied. Jonathan and Yates come next, followed by Dunns, Cox's Orange Pippin, Granny Smith, and Delicious. Rome Beauty forms its fruit buds later than any of the other varieties, being approximately one month after Cleopatra.

(*d*) *Individual Tree Variation.*

The initiation of fruit buds may occur at different times in trees of the same variety during the same season in the one orchard. Buds from two Granny Smith trees at Blackwood, S.A., were examined separately during 1930-31. Whereas the time of differentiation was 2nd January, 1931, for one tree fruit bud, initiation did not take place until 18th January, 1931, in the other. These trees were on different stocks; details of their constitution have been given elsewhere (5). During 1933-34 buds were collected from six trees of Jonathan at Templestowe in Victoria, and each collection of buds was examined separately. Differences in development equivalent to a difference of about one week in the time of fruit bud formation occurred between the individual trees. That such differences may occur in the time of fruit bud formation in apparently comparable trees makes comparisons between varieties, seasons, and locations rather difficult and unreliable. Nevertheless, the method adopted in these studies of making composite samples of buds from five trees has probably given a mean value which may be justifiably used for these purposes.

4. The Time of Differentiation of the Fruit Buds of the Stone Fruits.

In Table 3 the dates of fruit bud differentiation, which have been determined as described for apples, are given for the varieties of drupaceous fruits examined during the seasons 1930-31 to 1932-33:—

TABLE 3.—TIME OF FRUIT BUD DIFFERENTIATION.*

Stone Fruits.

Variety.	Locality.	Season 1930–31.	Season 1931–32.	Season 1932–33.
Grand Duke (European Plum)	Templestowe, Vic. ..	2.1.31	7.1.32	2.1.33
Prune d'Agen	Shepparton, Vic. ..	..	17.1.32	13.1.33
Moorpark Apricot ..	Templestowe, Vic. ..	30.1.31	1.2.32	1.2.33
,, ,, ...	Shepparton, Vic. ..	19.1.31	30.1.32	26.1.33
,, ,, ...	Canberra, F.C.T. ..	..	..	11.3.33
Anzac Peach	Templestowe, Vic. ..	16.1.31	21.1.32	17.1.33
Pullar's Peach	Shepparton, Vic. ..	19.1.31	22.1.32 Circ.	17.1.33
Satsuma (Japanese Plum) ..	Templestowe, Vic. ..	16.2.31	18.2.32	16.2.33
Burbank (Japanese Plum) ..	Canberra, F.C.T. ..	..	..	6.2.33

* For type of buds, i.e., terminal or axillary, for each variety, see Section 2B above.

Fruit bud differentiation in the stone fruits occurred later in the season than in apples and pears. The Grand Duke plum was the first of the drupaceous fruits to form fruit buds at Templestowe; the Anzac Peach buds differentiated about a fortnight later, followed by the Moorpark apricot a fortnight later again, and finally the Satsuma plum more than a fortnight later still. At Shepparton, Prune d'Agen differentiated a few days ahead of Pullar's Peach with the Moorpark apricot a few days later. The two varieties of *Prunus domestica* were the first to form fruit buds, and were followed by varieties of *Prunus persica* (the peaches), *Prunus armeniaca* (the apricot), and *Prunus salicina* (the Japanese plums) in order. The difference in the time of differentiation between the apricot, plum, and peach was more marked at Templestowe than at Shepparton.

There was very little difference in the time of differentiation in the one variety during different seasons. Both at Shepparton and Templestowe, differentiation was a little later in 1931-32 than in the other two seasons for all varieties. The difference was most marked in the apricot at Shepparton.

5. The Relation of Shoot Growth and Meteorological Conditions to Fruit Bud Initiation and Development.

(*a*) *Time of Differentiation and Shoot Growth.*

Observations of the seasonal development and measurements of shoot growth of the trees in Victoria, from which buds were sampled, were made during 1931-32 and 1932-33 in the same manner as in 1930-31 (4, 6, 7, 8). During the two later seasons some additional aspects of vegetative activity were included in the records, which comprised weekly measurements of the length and circumference of

several leading shoots and laterals, the growth of the spur leaves, and the increase in the circumference of trunk and main arms of each tree. Dates of bud-burst, blossoming, and defoliation were recorded for most varieties. The records of each unit of growth were, however, insufficient for a satisfactory comparison of the behaviour of the trees in different seasons and for the correlation of the periods of vegetative growth with the time of fruit bud formation. Such conclusions as may be drawn from the data are in agreement with the views previously expressed (4, 6, 7, 8), viz., that a relationship exists between the cessation of shoot elongation, the secondary thickening of the shoots, and fruit bud initiation. Those varieties which cease shoot growth earliest in the season tend to differentiate their fruit buds first.

The growth records of the Tasmanian apple trees during 1932-33, and 1933-34 were of the same nature as those made during the same seasons in South Australia (5). These comprised, in addition to the records of phenological data such as blossoming time, the measurement of the length and circumference of ten leading shoots and spur leaves at approximately weekly intervals during the growing season. The mean date of the cessation of the growth of the leading shoots and the time of differentiation for the apples in South Australia and Tasmania are set out in Table 4.

Table 4.—Cessation of Shoot Growth and Fruit Bud Differentiation.

Variety.	Locality.	Season.	Date of Cessation of Elongation Growth.*	Time of Differentiation.
Jonathan	Blackwood, S.A. ..	1932–33	2.1.33	21.12.32
		1933–34	27.12.33	20.12.32
Dunns	Blackwood, S.A. ..	1932–33	4.1.33	24.12.32
		1933–34	25.12.33	..
Cleopatra	Blackwood, S.A. ..	1932–33	15.1.33	24.12.32
		1933–34	3.1.34	13.12.33
Granny Smith ..	Blackwood, S.A. ..	1932–33	24.1.33	4.1.33
		1933–34	9.1.34	1.1.34
Cleopatra	Huonville, Tas. ..	1932–33	18.1.33	6.1.33
		1933–34	27.12.33	28.12.33
C.O.P.	Huonville, Tas. ..	1932–33	18.1.33	12.1.33
		1933–34	5.1.34	7.1.34

* Mean of ten shoots.

These data indicate that there is a general association between the date of cessation of shoot growth and the time of fruit bud formation,

i.e., early cessation of shoot growth accompanies early differentiation. By taking a mid-point between the dates of cessation of growth and maximum rate of growth, a more reliable index for comparing shoot growth in different seasons is obtained. There is a close association between the date so calculated and the time of fruit bud formation. Differentiation occurred 21 days after this date during both seasons in Cox's Orange Pippin, and fourteen days after in Cleopatra in Tasmania, and fourteen days after in Granny Smith in South Australia. In Jonathan, differentiation was ten days later in one season and twelve days in the other, two and four days later in Cleopatra in South Australia, and ten days later in Dunns. It is to be remembered in this connexion that the Cleopatra trees in South Australia were grown on Northern Spy stock while those in Tasmania were on seedling stock.

An analysis of other data from Tasmania strongly confirms the conclusions previously made (5) regarding apples in South Australia. Vegetative growth is less vigorous during the "on" season than during the "off" season. The carrying of the heavy crop tends to cause an early cessation of shoot growth, the production of shorter shoots with shorter internodes, and less leaves. This less vigorous shoot growth is accompanied by a slightly earlier differentiation of the fruit buds than occurs during the "off" season.

(*b*) *Time of Differentiation and Meterological Conditions.*

Meteorological records comprising rainfall and mean monthly temperatures were kept for all stations in Victoria, South Australia, and Tasmania, during the seasons under consideration. In addition, the hours of bright sunshine for each month were recorded for the Templestowe district in Victoria and Blackwood, South Australia. These records fail to reveal any definite relation between seasonal conditions and the variation in the time of fruit bud formation from season to season, though the evidence suggests that drought induces early differentiation.

(*c*) *Development subsequent to Differentiation.*

The development of the fruit buds after differentiation was recorded for all varieties during each season in a tabulated form comparable to that of Table 1. On the basis of these data, comparisons were then made between the rate of development of the fruit buds during different seasons. In the Yates, Jonathan, and Rome Beauty apples at Templestowe, though differentiation in each variety occurred at different times during the three seasons, there was little difference in the stage of development reached about one month after differentiation. By late February, practically the same stage was reached in all seasons and from March onwards development was similar in 1930-31 and 1931-32, and slightly more rapid than in 1932-33. The slower development in the latter season was probably due to the heavy "on" crop in that year.

Very little difference was apparent in the rate of development of the buds of the stone fruit at Templestowe during the three seasons of observation. It seemed, however, that drought conditions tended to retard development, and this conclusion is supported by observations on the Satsuma and Burbank plums at Canberra.

In Dunns apple at Harcourt, a similar stage of development was reached by February in all three seasons, and in Cleopatra by March.

From March onwards very little difference could be detected in the rate of development during the different seasons.

The development of the apple buds in South Australia has been described elsewhere (5) in detail. Such differences as occurred in the rate of development of the buds of the same variety during different seasons seemed to be definitely related to the amount of fruit carried. The rate of development during February and March was apparently retarded by the presence of a heavy crop. In the case of late-harvested varieties, the effect was most marked and extended over April.

A comparison of the rates of bud development in Cox's Orange Pippin and Cleopatra at Huonville, confirm the conclusions regarding varieties in South Australia. In both varieties differentiation was earlier in 1933-34 than in 1932-33. Until the beginning of February, the rate of development was similar in both seasons, and thus development during 1933-34, continued in advance of that of 1932-33. During February and March, however, the rate of development was slower during 1934 than during 1933. The crop was harvested from the second week in March in 1934, and following harvest the rate of bud development accelerated. It was not until May that the same stage was again reached in 1934 as in 1933. The rainfall during the summer of 1933-34 was particularly low at Huonville, and the drought condition which obtained may have contributed to slowing down the rate of bud development during this "on" crop season.

(d) General Conclusions.

The variation from season to season in the time of bud differentiation in stone fruits is small, and it is difficult to relate such differences as do occur to seasonal conditions. In pome fruits the time of bud differentiation seems to be more closely related to the size of the current season's crop and to the time of cessation of shoot elongation growth than to climatic conditions. Shoot elongation is also more closely related to the amount of fruit carried than to meteorological conditions. Shoot growth ceases earlier and fruit bud initiation occurs earlier in the "on" than in "off" crop seasons. There is also a relation between the normal time of the cessation of shoot growth in different varieties and the time at which fruit bud formation occurs. Those varieties in which growth ceases early tend to differentiate their buds early in the season. Generally speaking, all the evidence indicates that differentiation occurs latest in the trees of the one variety which are most vigorous and vegetative. Studies elsewhere indicate that irrigation delays differentiation while drought conditions induce an early initiation of fruit buds.

The development of the buds after differentiation proceeds at very much the same rate in one variety each season. The factor which affects the rate of development most markedly is the amount of fruit matured. Some evidence also suggests that drought conditions delay development.

It appears that factors which tend to depress vegetative growth induce an early differentiation of the buds, but after differentiation has occurred conditions which favour shoot growth also tend to accelerate the development of the fruit buds. Heavy crops and drought conditions which retard shoot growth have a similar effect upon the growth of the fruit buds.

6. Acknowledgments.

The studies in Victoria and South Australia were made in co-operation with the respective Departments of Agriculture. The author is indebted to Mr. F. M. Read, Chief Horticultural Inspector, Department of Agriculture, Victoria, for the collection of bud material, growth records, and meteorological data for Victoria, and to Mr. R. H. Fowler for similar services in respect to the studies in South Australia. He is also grateful to Mr. W. M. Carne of the Division of Plant Industry, for the collection of bud material in Western Australia as well as for growth records in Tasmania.

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The Occurrence of Stick-Fast Fleas in Queensland.

*By I. M. Mackerras, M.B., Ch.M., B.Sc.**

Summary.

Echidnophaga gallinacea and *E. myrmecobii* are recorded from dogs in South Queensland. The former is a well-known pest of poultry and dogs in Western Australia, but it has not previously been found in the eastern States.

The stick-fast fleas form a small group, sharply differentiated from other fleas by their greatly compressed thorax, giving them a specially hunched up appearance, by their serrated mouth parts by which they adhere to their host, and by their relatively weak legs. Their habits, too, are very distinct, for they are not actively mobile, but remain fixed to their host, frequently in masses, for long periods with their mouth parts buried in the skin. They may cause a considerable amount of irritation.

Five species have been recorded from Australia, all belonging to the genus *Echidnophaga*, but only two, *E. gallinacea* Westw. and *E. myrmecobii* Waterh., are sufficiently common to attract attention from other than specialists. Both are characterized by possessing a row of three large bristles and one smaller one on each side of the fifth tarsal segment. *E. gallinacea* has in addition a pair of apical, median, ventral bristles on the fifth tarsal segment, whereas *E. myrmecobii* has only a single bristle in this situation.

E. gallinacea is probably an introduced species. It is widespread in Western Australia as a pest of poultry and dogs, and has also been found attacking horses, rabbits, rats, man, and the native rabbit bandicoot (*Thalacomys lagotis*). Ferguson (1923)† noted that it was spreading eastwards, and recorded specimens from rabbits in the Eucla district and from a dog and a child at Ooldea, South Australia.. He pointed out that there was grave danger of its introduction into the eastern States, and urged that the importation of birds from Western Australia should be subject to rigorous quarantine. That the danger was appreciated is shown by the promulgation of quarantine regulations prohibiting the importation of poultry from Western Australia and the Northern Territory (where it also occurs) into other parts of the Commonwealth, unless accompanied by a certificate of freedom from stick-fast fleas.

Several stick-fast fleas were collected by Mr. W. I. B. Beveridge in March, 1935, from dogs on a property near Dirranbandi, South Queensland. They have been compared with specimens from dogs and fowls in Western Australia, and all but one are undoubtedly *E. gallinacea*. Mr. Beveridge's notes about them are of considerable interest:—

"They are very prevalent here on the dogs, and are said to have been here at least ten years. I have not been able to find any on the

* An officer of the Division of Economic Entomology.

† *Australian Zoologist* 3: 117-118, 1923.

fowls. Some of the locals call them the 'red rabbit flea,' but I have searched several rabbits for them with negative results. On the other hand, all dogs here are infested all the time. They are confined to the scrotum, perineum, muzzle, and, in short-haired dogs, the tips of the ears. They are firmly attached, and require quite a pull to remove them. They cause a certain amount of irritation, but dogs which live here pay little or no attention to moderate numbers. Sometimes, however, they pack on very thickly, and there may be hundreds on a dog's scrotum. An infusion of derris root is a highly effective treatment."

For a long time no further records were obtained, but recently Dr. J. H. Riches collected a large number of *E. gallinaceae* from the ears of dogs on a property 40 miles north of Cunnamulla (Q.). He could find none on dogs or rabbits further south in the same district, although local graziers stated they knew the fleas, which they believed killed many rabbits.

These records are confirmed by a specimen collected in 1932 by Dr. F. H. S. Roberts, of which he writes—(personal communication):—"The single specimen taken by me from a dog was secured on a property near Boomi, New South Wales. My identification was confirmed by Ferris, to whom the specimen was submitted."

There is no doubt, therefore, that *E. gallinacea* is widely established in a belt of country between the Macintyre and Warrego Rivers, but so far it is not known whether it extends beyond these limits. It does not appear to be important as yet, but Ferguson notes that it was certainly present in Western Australia for years before it became a serious pest. It would be wise of those who keep dogs or fowls to look out for it, and be prepared to take preventative measures.

In the series collected from dogs near Dirranbandi, there was a single specimen of *Echidnophaga myrmecobii*. This species is a native, and Ferguson suggests that it may also become a farmyard pest. It is widely distributed in New South Wales, Victoria, South Australia, and Western Australia, and is now recorded from Queensland.

It also has a wide range of hosts, having previously been taken on the opossum (*Trichosurus vulpecula*), rat-kangaroo (*Bettongia lesueuri*), banded ant-eater (*Myrmecobius fasciatus*), rabbit bandicoot (*Thalacomys lagotis*), jerboa rat (*Leporillus jonesi*), brown snake (*Demansia textilis*), and the introduced rats (*R. rattus* and *R. norvegicus*), and rabbit.

The Rapid Measurement of Moisture Content. An Industrial Use of Changes in Dielectric Properties.

By A. J. Thomas, Dip. For., I.F.A. and C. J. Irvine.†*

Summary.

The comparison of the change of capacity of an individually calibrated variable condenser necessary to restore to resonance a parallel tuned circuit has been used to indicate the moisture content of cheese.

An inexpensive and simply operated instrument has been developed. Its suitability for this particular purpose is still being investigated, but it should have other applications either in its present form or after modification.

I. Introduction.

Following the publication in the August 1937 issue of this Journal of a description of a new instrument for the determination of the moisture content of timber by electrical capacity effects, several inquiries have been received regarding the possible application of the same principle to other materials. One inquirer wished to test small pieces of cheese with a moisture content around 40 per cent. and required a determination accurate to ½ per cent.

The original instrument could be made sufficiently sensitive but was not stable enough to provide the desired accuracy indefinitely and, furthermore, the capacities involved were so small that external conditions had too great an effect. To meet the commercial requirements, an instrument was required to measure capacities ranging from about 10 to 100 m.mfd. quickly and simply to 1 m.mfd.

Such an instrument was developed and handed over to the firm concerned who have been experimenting for the last six months with various types of electrodes and cheese. It is too early to say whether the moisture content of cheese can be determined in this way, but as the instrument itself has proved satisfactory and very simple to use, it should have many other applications. Consequently, it has been decided to publish the particulars given herein.

2. Description of Instrument.

General.

The instrument consists of two high frequency circuits normally in resonance. Two metal electrodes with the cheese between them and a calibrated condenser are connected in parallel in one of the circuits, and resonance is maintained by adjusting the calibrated condenser to compensate for the effect of the cheese. Resonance is indicated by a 6E5 cathode-ray tuning-indicator valve, commonly called a "magic-eye."

Readings to apparently 1 m.mfd. may be made with a flick of the wrist, there being no difficulty in finding the resonance point.

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List of Components.

These numbers correspond with those shown on the circuit diagram, Fig. 1:—

1. Piezo electric quartz crystal, approximately 3660 kc., and mounting.
2. 100,000 ohm, 1 watt resistor.
3. 76 type valve and 5 pin socket.
4. .002 mfd. mica fixed condenser.
5. 500 ohm, wirewound resistor.
6. Midget variable condenser (100 m.mfd. maximum capacity).
7. .005 mfd. mica fixed condenser.
8. Coil.
9. Coil link.
10. Coil.
11. Connexions to external electrodes.
12. Midget variable condenser, low loss high grade type (Capacity 3 to 20 m.mfd.).
13. Midget variable condenser, low loss high grade type (Capacity (6 to 100 m.mfd.).
14. 76 valve and 5 pin socket (or suitable diode).
15. .002 mfd. mica fixed condenser.
16. 200,000 ohm, 1 watt resistor.
17. $1\frac{3}{4}$ megohm resistor.
18. 6E5 valve and 6 pin socket.
19. 1 megohm resistor.
20. Power transformer.
    Primary—tapped for 210, 230, 250 volts.
    Secondaries—(*a*) 385 volts, 60 m.a., centre tapped.
    (*b*) 5 volt.
    (*c*) 6.3 volt, centre tapped.
21. 80 full wave rectifying valve and 4 pin socket.
22. Power supply choke.
23. } 8 mfd. electrolytic condensers, 600 v.
24. }
25. 15,000 ohm. voltage divider.

Circuit.

The circuit used is shown in Fig. 1. The instrument consists of an oscillator, a diode detector, a cathode-ray tuning indicator, and a power supply unit.

All the components are standard radio equipment except the coils. Provided ordinary good practice is followed, construction presents no difficulty. The components may be assembled on an aluminium chassis and should be arranged so that all wires carrying high frequency currents are short, spaced, and not parallel. Stiff wire is better than flexible wire. The moving plates of the variable condensers should be earthed, and all earthed points should be connected together with copper wire 18-gauge or thicker.

Coil System.

The two coils (8) and (10) are wound with 18-gauge enamelled wire on separate $1\frac{1}{4}$-in. diameter ribbed composition formers, and housed in separate 2-in diameter 18-gauge aluminium shielding cans. Coil (8) consists of 29 turns, the first turn commencing $\frac{3}{4}$ inch from the bottom

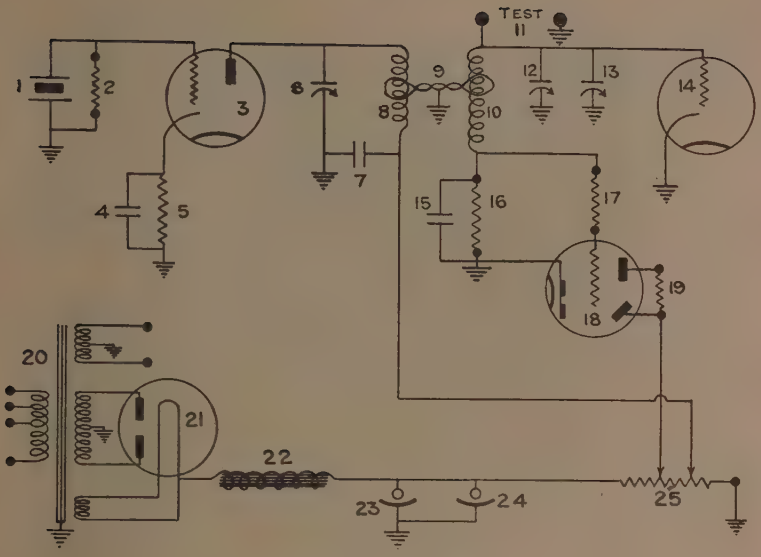

FIG. 1.—Circuit diagram.

and being connected to the 200 volts positive tapping on the voltage divider (25). Coil (10) consists of 27 turns, the first turn commencing $\frac{1}{2}$ inch from the bottom and the top turn being connected to the grid of the second valve (14). The coils are coupled by a twisted link (9) consisting of one turn around the bottom of coil former (8) and two turns around the bottom of coil former (10) with the centre point connected to earth.

Oscillation Control.

Control of oscillation is provided by a variable condenser (6). Rotating the plates one way will bring the valve into oscillation gradually, and continued rotation will cause the valve to stop oscillating suddenly. If rotated back, the valve will come into oscillation suddenly and fall out gradually. The instrument should be used with the condenser set on the stable side of the peak point. This control also enables the observer to adjust the appearance of the "magic-eye" when it is indicating resonance. If the valve is oscillating quietly, the dark sector will not quite disappear, whereas if oscillating violently the edges of the green sector will overlap to form a bright sector. This is very useful because it has been found that different observers have their individual preferences. Alteration of the oscillating plate tuning condenser has some influence on the frequency of oscillation and some influence on accuracy of readings, but for practical purposes the error introduced is insignificant.

Valves.

From the circuit it will be seen that two 76 triode valves are used. These were not chosen deliberately but happened to be the only valves on hand. The second valve is being used as a diode, with the plate unconnected.

Possible Improvements.

This instrument must be regarded as being an experimental model, built with components on hand. Various improvements are possible, e.g.,

(1) A more stable oscillator circuit using a penthode valve and a crystal-cut of low temperature co-efficient.

(2) A different resonant circuit to obviate the excessive damping of a diode rectifier and so obtain a sharper resonance curve.

(3) The resonance indicator—here the 6E5—might be removed from the grid circuit.

Recent Investigations on the Buffalo Fly (*Lyperosia exigua* de Meijere) and its Parasites in North Australia.

*By T. G. Campbell.**

1. Introduction.

Four years ago, a Javanese parasite, *Spalangia sundaica* Graham, was introduced and liberated in suitable areas at Burnside and Marrakai Stations, Northern Territory, as a possible means of controlling the buffalo fly (*Lyperosia exigua* de Meij.). The introductions followed intensive investigations on the fly and its parasites by Professor E. Handschin† and G. L. Windred‡, at Buitenzorg, Java. (1)

The object of this paper is to give a short account of the most recent investigations into the buffalo fly and the two parasites of the genus *Spalangia* (Pteromalidae) which attack it in North Australia. These investigations were carried out between 26th March and 11th June, 1936.

During this period, the abundance of *Lyperosia*, the extent of the injuries produced in stock, and the incidence and fertility of *Spalangia*, were re-examined in areas where the introduced parasites had been liberated and also in other areas for comparison. Most of the investigations were carried out at Burnside, but in addition field observations were conducted at Marrakai and Litchfield Stations. (See map.)

2. Abundance of *Lyperosia*.

Observations on the abundance of *Lyperosia* were made by visual estimates of density and distribution on numerous individual cattle. These observations were commenced at Burnside Station, at the latter end of March, 1936, when the wet season was practically at an end, and were continued until early in June. Visual observations on fly density on the more heavily infested cattle under observation were supplemented by a count of flies, taken each day in a single sweep of the net. In this manner a daily average of 531 flies were taken throughout April, the numbers varying from a minimum of 78 to a maximum of 1,023. Samples were taken almost invariably from the flanks of animals, where the flies usually occurred in greatest numbers.

Both counts of flies and visual observations were supported by photographic records throughout the course of the investigations, and, notwithstanding an exceptionally light wet season, it was quite obvious that the abundance of the fly was similar to that in other years before the parasites were liberated. Typical damage caused by the attack of the fly, characterized by sores under the eyes and on the neck and dewlap,

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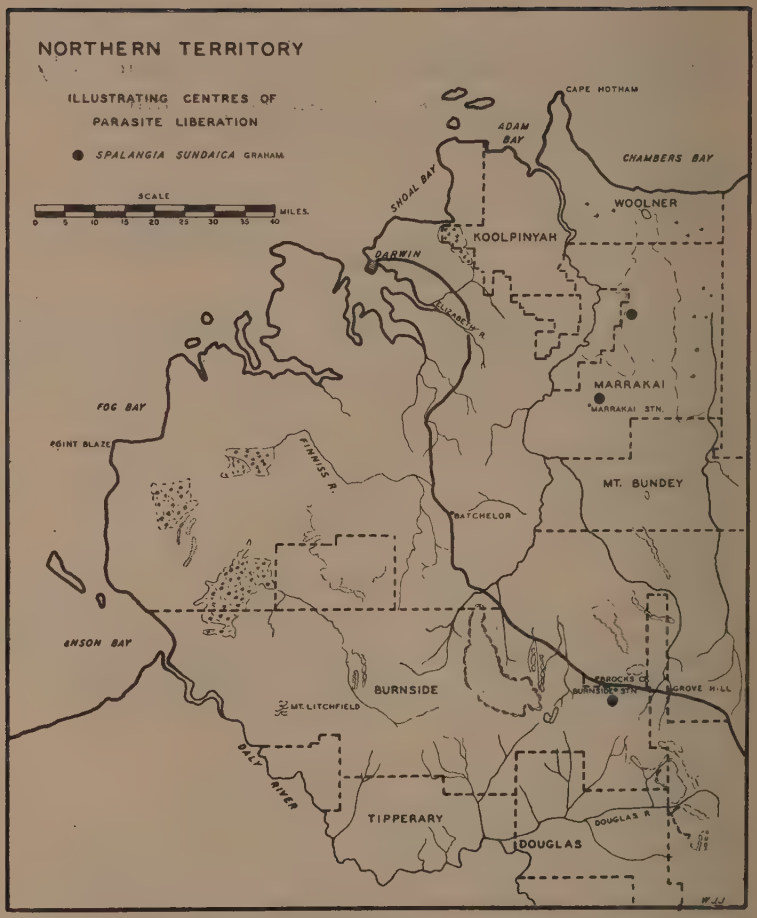
† Of the University of Basle, Switzerland; he spent some two years in Java and Australia investigating the buffalo fly problem on behalf of the Council for Scientific and Industrial Research.

‡ At that time an officer of the Division of Economic Entomology.



were of much the same extent as formerly. (Plate 1, Figs 1, 2, and 3.) On some animals fly scars remained in a raw state until the dry season was well advanced.

A comparison of the successive wet season rainfall records over the period following the introduction of *Spalangia sundaica* (Table 1) gives an idea of the varying conditions affecting host and parasite in the areas of liberation. During these years the earliest rains were recorded in October, the greatest falls being from then on until March in each year, though isolated falls were recorded as late as June during some years. It will be noted that the rainfall during 1935-36 was far below that of other years. As a result, large areas in the Northern Territory experienced one of the worst years in the history of the pastoral industry. It was under the exceptionally dry conditions which prevailed after the 1935-36 wet season that the recent investigations were carried out.

TABLE 1.—SEASONAL RAINFALL RECORDS—BURNSIDE STATION.
In points (1 *point* = 0.01 *inch.*)

Wet Season.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Total.
1932–33	26	700	1,320	573	734	1,532	..	12	25	..	..	..	4,922
1933–34	32	496	1,275	1,134	825	1,784	..	..	..	..	..	..	5,546
1934–35	117	399	277	924	934	1,538	..	..	132	..	..	..	4,321
1935–36	78	366	395	438	775	92	137	24	..	..	..	..	2,305

3. Parasite Incidence Under Field Conditions.

In order to arrive at an estimate of the amount of parasitism by the various forms* of *Spalangia sundaica* and *S. orientalis* (2) in the field, large series of Lyperosia puparia were collected from the several localities at Burnside and Marrakai Stations, where liberations had been made during 1932 and 1933. Two areas had been selected in 1932, owing to their suitability for the liberation of parasites and for observations on their subsequent behaviour. Descriptions of these two areas are as follows:

(*a*) *Night Paddock—Burnside Station.*

A small paddock adjacent to the homestead drafting yards, where fly-infested dairy cattle were yarded each night, and where there was continuity of occupation throughout the year. The area of this paddock was approximately 16½ acres. Puparia were also collected from the immediate vicinity, as cattle grazed over the whole area. In this situation the form produced by crossing *Spalangia sundaica* ♂ with *Spalangia orientalis* ♀ was liberated during 1932-33.

(*b*) *Collins' Paddock—Burnside Station.*

A paddock about one mile square, containing three or four more or less permanent waterholes, and situated from one to one and a half miles from the Night Paddock. The cattle population of Collins' Paddock varied from 10 to 20 head kept for the supply of beef throughout the year. In this area a pure line of *Spalangia sundaica* was liberated during the same period in 1932-33. The first liberations were made in May, 1932, and during the following twelve months 864 parasites were liberated in the Night Paddock and 2,651 in Collins' Paddock. Parasites were also liberated in other suitable areas in the neighbourhood of Burnside Station, and mass liberations of infected puparia were also made in the Night Paddock.

The results set down in Table 2 are from records of the incidence of *Spalangia* in buffalo fly puparia between 25th March and the end of May, 1933, compared with records made during the corresponding period of 1936. The increased percentage of parasitism four years after the introduction of *Spalangia sundaica* amounted to 4.85 in the Night Paddock and 3.18 in Collins' Paddock, which is so small as to have little, if any, significance.

* As no detailed study has so far been made of the characters of hybrids produced by crossing the two species of *Spalangia*, the writer has refrained from using a more specific designation than the word "form."

TABLE 2.—PARASITE INCIDENCE—1933 AND 1936.

Locality.	Parasite.	1933.			1936.		
		No. Puparia.	*Spalangia.*	Percentage Parasite.	No. Puparia.	*Spalangia.*	Percentage Parasite.
Night Paddock, Burnside Station	*Spalangia sundaica* ♂ x *Spalangia orientalis* ♀	863	32	3·7	2,594	222	8·6
Collins Paddock, Burnside Station	*Spalangia sundaica* ♂ x *Spalangia sundaica* ♀	1,259	152	12·1	4,425	675	15·3

4. Fertility and Longevity of *Spalangia.*

As previously stated, various forms of *Spalangia sundaica* and *S. orientalis* were liberated in selected localities on Burnside and Marrakai Stations during 1932 and 1933. During that time also, a series of laboratory experiments were in progress to determine the lifetime and fecundity of the various forms of parasites which were being bred and liberated.

The various forms experimented with were:

(*a*) A pure strain of *Spalangia sundaica* bred from material introduced from Java in April, 1932. Liberations of this wasp were made in the area referred to as Collins' Paddock.

(*b*) A hybrid using *Spalangia sundaica* ♂ and *Spalangia orientalis* ♀. These hybrids were liberated in the vicinity of the area referred to as the Night Paddock. In addition a number of males of *Spalangia sundaica,* were liberated in the same situation, so as to pair with females of *Spalangia orientalis* under natural conditions.

(*c*) The Australian *Spalangia orientalis.*

During the course of the recent investigations, a series of breeding experiments were carried out to obtain data on the longevity and fecundity of parasites from various centres of liberation. To carry out these experiments it was necessary to breed puparia under parasite-free conditions. They were bred by obtaining fresh dung from cattle adjacent to the field station, and placing adult flies on the dung immediately it was collected. The trays and tubes containing the dung and flies were then transferred to a gauze insectary, where the new generation of *Lyperosia* was allowed to develop.

This work was commenced at the end of April, with three experiments for each form of *Spalangia.* Parasites used in these experiments were obtained from localities where the following conditions governed the liberations made four years previously:—

(*a*) Where a pure strain of *Spalangia sundaica* had been liberated.
(*S. sundaica* ♂ x *S. sundaica* ♀)
Collins' Paddock, Burnside Station.

(*b*) Where males of *Spalangia sundaica* had been crossed with females of *S. orientalis.*
(*S. sundaica* ♂ x *S. orientalis* ♀)
Night Paddock, Burnside Station.

(*c*) Where no liberations had been made and the parasites were considered to be a pure strain of the indigenous species, *S. orientalis*.

(*S. orientalis* ♂ x *S. orientalis* ♀)

Bridge Creek Turn-off. (About 2 miles distant from the Night Paddock.)

A series of 25 fresh puparia were offered to each pair of wasps every two days, all puparia being of the same age. In addition a series from each culture offered to the parasites was kept as a control, to show that there was no parasitism from extraneous sources.

TABLE 3.—COMPARISON OF THE AVERAGE LIFETIME AND FECUNDITY OF FEMALES OF THE THREE FORMS OF "SPALANGIA" BRED DURING 1932-1933 WITH SIMILAR EXPERIMENTS IN 1936.

Parasite.	1932–1933.			1936.		
	No. of Experiments.	Lifetime of ♀ (Days).	Fecundity.	No. of Experiments.	Lifetime of ♀ (Days).	Fecundity.
Spalangia sundaica ♂ x *Spalangia sundaica* ♀	103	21	70	3	22	103
Spalangia sundaica ♂ x *Spalangia orientalis* ♀	3	24	87	3	25	93
Spalangia orientalis ♂ x *Spalangia orientalis* ♀	3	30	92	3	21	99

The number of experiments was too small to determine whether there was any difference between the forms, but it is reasonable to suspect that, if there were a difference, it was not large.

5. Summary and Conclusions.

Observations on the density of the fly in localities where parasites had been liberated, showed that their numbers were much the same as in previous years. Damage to stock was also in the same proportions as formerly, though perhaps the abnormal season, 1935-36, may have to some extent reduced the severity of the attack.

Following an exceptionally light wet season, the rapid drying of the soil, low humidity, and generally unfavorable conditions, all aided in retarding the breeding of *Lyperosia*. However, in spite of these adverse conditions, the fly was still quite plentiful on the completion of the investigations early in June.

An analysis of the parasite incidence from comparatively long series of puparia collected from selected centres of liberation showed no marked increase in parasitism. In both areas where detailed studies of the parasite incidence were carried out, the increase amounted to less than 5 per cent., and no significance can be attached to such small

variations. Parasite incidence in Collins' Paddock was somewhat greater than in the Night Paddock, but conditions in the latter area were distinctly less favorable to the breeding of puparia. The records of breeding experiments to test the longevity and fecundity of different forms of parasites from separate centres of liberation, showed no appreciable increase in the lifetime of the parasites or their powers of reproduction had taken place. A comparison of the records shows that the average lifetime and fecundity differed to such a small extent in the various experiments, as to have little, if any, significance. In view of the fact that all parasites from the several localities have been identified as the same species, viz., *Spalangia orientalis,* the variations in the 1936 experiments on the lifetime and fecundity of *Spalangia,* may be considered to be fortuitous.

As a result of the recent observations and experiments, it would appear as if the introduced parasite has either failed to become established or else has been completely merged by inter-breeding with the indigenous form. In any case the survey has shown that this parasite has had no appreciable effect on the abundance of *Lyperosia,* or the damage which their attacks cause to stock.

In view of the results obtained in the Northern Territory, it was considered that no good purpose could be served by any similar investigations at either Augustus Downs or Mornington Island, the two North Queensland localities in which liberations of *Spalangia sundaica* were made during 1932.

6. Acknowledgments.

The writer wishes to acknowledge his indebtedness to Dr. C. Ferrière of the Imperial Institute of Entomology, London, for the identification of parasites from the several localities from which collections of *Spalangia* were made. Grateful acknowledgement is made for facilities provided by the Australian Investment Agency Limited, through the late Mr. C. W. D. Conacher, at its Burnside and Marrakai stations, and to Messrs. A. H. Wilson and W. Wyatt, managers of these properties, for their generous assistance during the course of the investigations.

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The Statistical Relation of Crop Size to the Incidence of Storage Disorders in Apples and to their Chemical and Physical Characters.

1. Results Obtained in 1936 and 1937.

By W. M. Carne, F.L.S., and D. Martin, B.Sc.**

1. Introduction.

Following upon work in Western Australia, investigations have been conducted in Tasmania by the writers into the factors associated with the susceptibility of apples to storage disorders. These Tasmanian investigations were commenced in the season 1932-1933. Probably their most unusual feature is that they have been based on individual tree units.

Amongst the conclusions reached are the following:—

(i) Within a variety, crop size, per tree, is an important, if not the most important, factor, in determining the liability of fruit to storage disorders (1).

(ii) That crop size and liability to storage disorders are correlated with certain chemical and physical characters of the fruit of any variety.

(iii) That conditions of crop size being similar, the liability of the fruit of any one tree to storage disorders is correlated with the seasonal climatic conditions prior to picking.

The association of relatively short storage life and high susceptibility to storage disorders with light or "off" crop fruits, as compared with heavy or "on" crop fruits, is widely recognized (2, 3, 4). Equally accepted is the fact that "off" crop fruit is relatively large as compared with "on" crop fruit, other factors being similar.

The alternation of "off" and "on" crops is characteristic of certain varieties, notably French Crab and Dunn's. A smaller range of crop from rather below to rather above average is very common in many varieties. All varieties are subject to marked alternation of light and heavy crops following a failure to bear a crop in any year. Widespread failure to crop may be due to late frosts, thrips, &c. Less obvious causes may be responsible for failure of individual trees to crop. Whatever the causes, it is characteristic of many varieties in Tasmania, notably Cox's Orange Pippin and Jonathan, that in any plot it is usual to find trees in "on," "off," and average cropping in the same year. So far as the writers are aware, the conclusions stated above have never been statistically confirmed. With this in view, the experiment outlined below was commenced in the 1935-6 season.

* An officer of the Council attached to its Division of Plant Industry and accommodated in Hobart by the University of Tasmania.

Variety.—Cox's Orange Pippin, selected on account of its high susceptibility to storage disorders.

Material.—A block of 21 trees approximately 20 years old (in 1936) and normally with "on," "off," and average cropping trees each season. The trees are rather dwarfed, being planted about 13 feet apart, on the square. The soil type is "Woodbridge Loam" (5).

Crop Size.—The relative crop size for each tree is determined by the average size of the fruit of each at the same date, 25th February. Some idea of the variation between tree crops may be shown by the range of average diameter size, different trees showing a range of 2.04 inches to 2.37 inches in 1936 and 1.92 inches to 2.25 inches in 1937.

Method.—The experiment is planned to be continued until sufficient data are accumulated to justify statistical analysis of the effect of climate. The time factor is important mainly in relation to the correlation with climate, and for obvious reasons the period of the experiment cannot be predetermined.

On the 25th February, 20 fruits per tree are picked at random for examination, and upwards of one box for storage purposes. This represents the greater part of the fruit of the "off" trees.

(*a*) The storage fruit is placed in cool store at 32-34 F. the day following picking and held there for ten weeks. It is then removed and measured and the average diameter determined for each tree. After three weeks at room temperature, it is cut up and examined for storage disorders.

(*b*) The 20 fruits per tree are examined the day after picking for—

(*a*) *Starch-iodine reaction* (a median transverse section of the fruit is stained with I-KI solution, and the proportion, in parts of ten, of the core area and cortex area where the starch has been hydrolized is estimated by eye and the sum taken (e.g., when the section of the apple shows 8/10 of the core clear and 3/10 of the cortex clear the S.I.R. figure is taken as 11).

(*b*) *Resistance to pressure,* using a standard U.S.A. penetrometer.

(*c*) *Ground colour,* taking the non-flushed side and estimating by eye, dividing from full green to full yellow into four stages on the basis of the change from green to yellow. No attempt is made to match the tint with standard colours. The value $2\frac{1}{2}$ would be given to the sample when the colour was midway between green and yellow.

(*d*) *Titratable acidity,* using 10 mil. of the juice of the cortical region titrated against N/10 NaOH using phenolphthalein as indicator.

(*e*) *pH,* using the juice of the cortical region and the quinhydrone electrode.

(*f*) *Refractive index,* using the juice of the cortical region and a Zeiss dipping refractometer with auxiliary prism.

2. Results—1936 and 1937.

With the results of crop size obtained in 1936 and 1937, the following possible correlations were tested, using the formula:—

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \, \Sigma(y - \bar{y})^2}}$$

where x and y are the values obtained for the two factors to be correlated, and x and y the mean of such values.

The value of p was found approximately from the table given in (6).

(*a*) Average size of the fruit per tree with—

1. Starch-iodine reaction.
2. Resistance to pressure.
3. Titratable acidity of juice.
4. pH of juice.
5. Refractive index of juice.
6. Percentage sound fruit after storage.
7. Percentage pitted fruit after storage.
8. Percentage breakdown fruit after storage.

(*b*) Titratable acidity with—

9. Percentage breakdown fruit after storage.
10. Resistance to pressure.
11. Refractive index of juice.

(*c*) Percentage pitted fruit with—

12. Refractive index of juice.
13. Starch-iodine reaction.

(*d*) Refractive Index with—

14. Resistance to pressure.

The results obtained are shown in the Table 1:—

TABLE I.

Correlation.	1936.			1937.		
	r.	*p.*	Significance.	*r.*	*p.*	Significance.
Average size of fruit-tree with—						
1. Starch–iodine reaction	−0·75	0·01	+	−0·72	0·01	+
2. Resistance to pressure	0·83	0·01	+	0·76	0·01	+
3. Titratable acidity	0·66	0·01	+	0·68	0·01	+
4. pH	No correlation		—	No correlation		—
5. Refractive index	0·0		—	0·42	0·05	?
6. Percentage sound fruit ..	−0·67	0·01	+	−0·65	0·01	+
7. Percentage pitted (total) ..	0·80	0·01	+	0·66	0·01	+
Percentage pitted (2¼-in. fruit)	0·58	0·01	+	0·56	0·01	+
8. Percentage breakdown (total) ..	0·65	0·01	+	0·55	0·01	+
Percentage breakdown (2¼-in. fruit)	0·52	0·02	+	0·74	0·01	+
(*b*) *Titratable Acidity with—*						
9. Percentage breakdown (total) ..	0·41	0·04	?	0·44	0·05	?
10. Resistance to pressure	0·69	0·01	+	0·87	0·01	+
11. Refractive index	0·09	..	—	0·73	0·01	+
(*c*) *Percentage Pitted Fruit with—*						
12. Refractive index	0·08	..	—	0·36	0·10	—
13. Starch–iodine reaction	−0·79	0·01	+	−0·77	0·01	+
(*d*) *Refractive Index with—*						
14. Resistance to pressure	0·01	..	—	0·64	0·01	+

3. Conclusions.

The results obtained in 1936 and 1937 give statistical confirmation of the conclusions arrived at in the apple investigations so far as they could be tested.

1. Positive correlations in both years were obtained between the average size of the fruit (a measure of the size of the crop) and the liability of the fruit to pit and breakdown; between the average size of the fruit and the titratable acidity of the juice, the penetrometer tests, and the starch-iodine reaction; between the titratable acidity of the juice and the penetrometer tests; and between the starch-iodine reaction and the pit liability.

2. No correlation was found between the average size of the fruit and pH, and refractive index of the juice; between the refractive index and pit liability.

3. The correlation between titratable acidity of juice and the percentage of breakdown was doubtful in both years.

4. There was a correlation between the refractive index of the juice and the titratable acidity and also the penetrometer tests in 1937, but not in 1936.

5. No correlations with the ground colour were obtained on the present basis of evaluating colour.

6. The possible correlation between climate and breakdown will require a range of seasons before it can be tested.

4. Acknowledgements.

The writers wish to acknowledge the assistance of the Council's Biometrician, Miss F. E. Allan, M.A., Canberra City, F.C.T.

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PLATE 1.

(Recent Investigations on the Buffalo Fly (*Lyperosia exigua* De Meijere) and its Parasites in North Australia. See page 77.)

FIG. 1. (left)—Lesion below eye caused by the attacks of *Lyperosia*, showing flies feeding.

FIG. 2. (right)—Lesions on dewlap, showing concentration of *Lyperosia*.

FIG. 3. (left)—Rubbing to relieve irritation increases the extent and severity of lesions as shown in FIGS. 1 and 2.

FIG. 4. (right)—A heavy infestation of *Lyperosia* on a buffalo-shooter's horse at Marrakai, N.T.

C.15164.

A View taken on the McMaster Field Station, near St. Mary's some 30 miles from Sydney.

NOTES.

The McMaster Field Station.

Animal health research cannot be conducted entirely in a laboratory, for it is essential to observe and experiment with groups of domesticated animals under controlled field conditions.

Sydney is the centre for the work of the Division of Animal Health and Nutrition on pastoral problems as they affect sheep, apart from those essentially nutritional in character, and this work is conducted in the F. D. McMaster Laboratory in the grounds of the University of Sydney, and at the McMaster Field Station, near St. Mary's, about 30 miles out of Sydney.

The steps leading up to the establishment of this field station were mentioned in a previous issue (9; 239, 1936). Briefly, in 1936, the Commonwealth Government purchased a property of approximately 850 acres and made this available to the Council. The University of Sydney purchased 400 acres immediately adjoining this property and is developing on it a farm containing a dairy herd, piggery, sheep, poultry, and horses for the purpose of facilitating the training in animal husbandry of students in the Faculty of Veterinary Science.

The 1,250 acres comprising the two properties are situated in undulating country facing the Mulgoa-road, bounded on the west by Cosgrove Creek and on the east by Badgery's Creek. Topographically, the whole property is not unlike a riding saddle. A central ridge forms the cantle, waist and pommel, while the flaps are represented by undulating country extending to the creeks where they finish as flats with a total area of approximately 160 acres, 100 of which are on Cosgrove Creek (see Plate 2). Each property thus has a long creek frontage.

The development of the Council's property has been made possible by funds made available by the Commonwealth Government, supplemented by the Australian Wool Board. Sir Frederick McMaster has also assisted by presenting 130 stud ewes and a team of four draught horses with harness and pasture improvement implements. Further, the family of the late Daniel Buffier has erected as a memorial to him a small laboratory which will serve the needs of the Station for laboratory facilities.

During the past year, much of the work on the property has been of a developmental nature comprising the provision of subdivisional fencing, sheep yards, wool shed, dip, and dams. In addition, a cottage for the overseer, and quarters for men, have been erected, and a house for the officer-in-charge is in the course of erection.

Approximately 125 acres have been allocated for parasitological problems, this area being subdivided into five paddocks, each of about 25 acres, with a frontage to Cosgrove Creek, and two 4-acre blocks each subdivided into acre lots (see plan on page 89). This area is provided with sheep yards and platform scales.

The remaining 725 acres are subdivided into three main groups of paddocks. The first group consists of five "ewe paddocks" and a "ram paddock," giving facilities for controlled matings and other observations being made in connexion with studies on fertility in sheep. The second group contains the shearing shed, dip, and principal sheep yards, as well as the men's quarters, stables, machinery and feed shed, and overseer's cottage. The third group of paddocks, situated on the north-eastern, north, and north-western boundaries, has a relatively large acreage and is used for general purposes.

From the main entrance on the Mulgoa-road, a gravel drive, approximately 1½ miles long, has been constructed along the crest of the central ridge. This passes into, and through, a portion of the University property, thus forming the main drive for both properties.

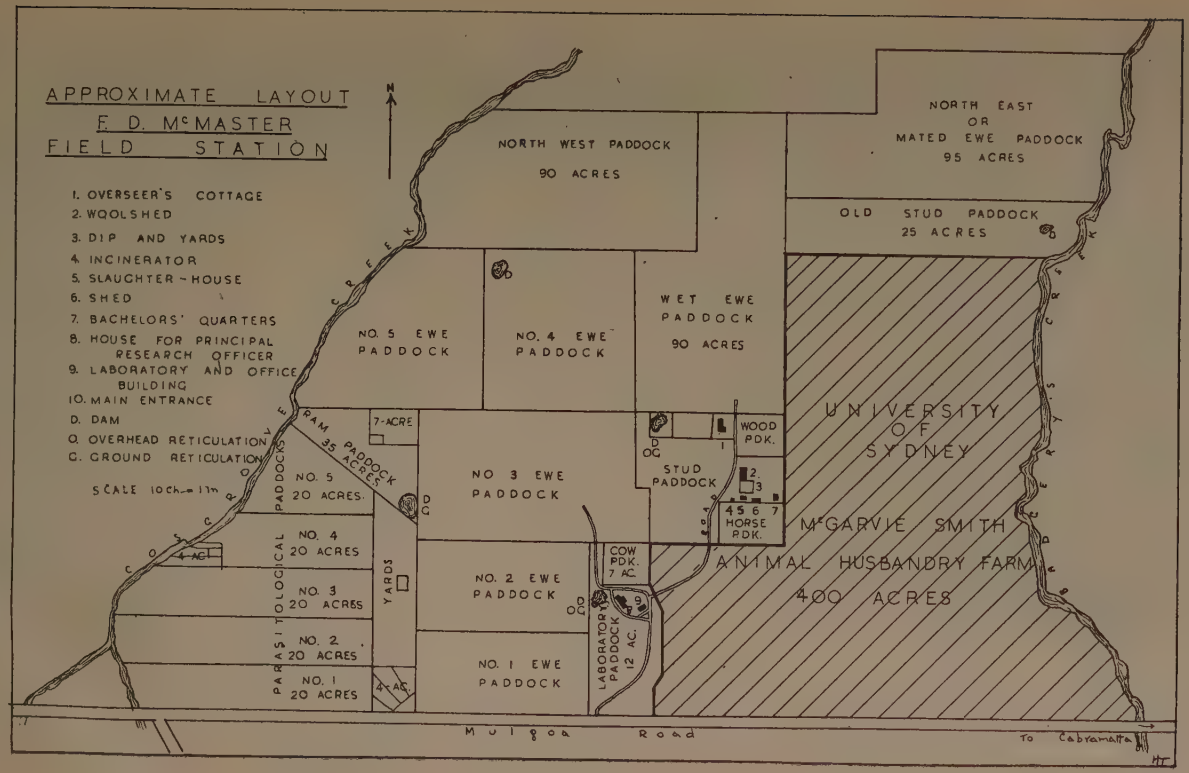
In addition to the developmental work, experimental observations have been carried out during the last year. Eight hundred and twenty-seven experimental sheep have been carried through one complete year with the assistance of a small amount of supplementary feeding, and 350 sheep have been provided for work at the McMaster Laboratory.

The natural pastures consist mainly of vigorous summer grasses, *Cynodon, Paspalum,* and *Sporobolus* spp., but have a low winter carrying-capacity. In order to overcome this deficiency and to increase the carrying capacity, a programme of pasture improvement has been commenced. An area of lucerne will be established in order to provide hand feed for the stock under more intensive observations at the McMaster Laboratory.

One function of the station is to form the centre for work of the Division on problems of animal genetics. At present three problems involving genetical studies are under investigation. Studies on fertility have already reached a stage enabling the publication of a progress report which is contained in Bulletin No. 112. Approximately 450 ewes and 40 rams are maintained for these investigations. Another problem under investigation is the inheritance of skin folds in Merino sheep, and the third is the inheritance of dark-coloured wool fibres in certain strains of Merino sheep.

A commencement has also been made with parasitological investigations. A study of the effects of heavy and light stocking on the degree of infestation with *Haemonchus contortus* is in progress, as well as a study of the factors associated with the viability of the larval form of *Haemonchus* under field conditions.

Studies are also being made on dips and their value in the control of ecto-parasites of sheep. An experimental study of pregnancy toxaemia, twin lamb disease, has also been commenced.


APPROXIMATE LAYOUT
F. D. McMASTER
FIELD STATION
1. OVERSEER'S COTTAGE
2. WOOLSHED
3. DIP AND YARDS
4. INCINERATOR
5. SLAUGHTER-HOUSE
6. SHED
7. BACHELORS' QUARTERS
8. HOUSE FOR PRINCIPAL RESEARCH OFFICER
9. LABORATORY AND OFFICE BUILDING
10. MAIN ENTRANCE
D. DAM
O. OVERHEAD RETICULATION
G. GROUND RETICULATION
SCALE 10ch = 1m
N
NORTH WEST PADDOCK
90 ACRES
NORTH EAST
OR
MATED EWE PADDOCK
95 ACRES
OLD STUD PADDOCK
25 ACRES
WET EWE
PADDOCK
90 ACRES
NO. 5 EWE
PADDOCK
NO. 4 EWE
PADDOCK
RAM PADDOCKS
35 ACRES
7-ACRE
NO. 5
20 ACRES
NO 3 EWE
PADDOCK
WOOD
PDK.
STUD
PADDOCK
HORSE
PDK.
UNIVERSITY
OF
SYDNEY
McGARVIE SMITH
ANIMAL HUSBANDRY FARM
400 ACRES
COW
PDK.
7 AC.
LABORATORY
PADDOCK
12 AC.
NO. 4
20 ACRES
NO. 3
20 ACRES
NO. 2
20 ACRES
NO. 1
20 ACRES
PARASITOLOGICAL PADDOCKS
YARDS
4-AC.
NO. 2 EWE
PADDOCK
NO. 1 EWE
PADDOCK
Mulgoa Road
To Cabramatta

Borers in Houses.

With the coming of summer, the Division of Forest Products is receiving its annual budget of inquiries concerning the powder-post borer which becomes more active as the weather grows warmer. Most householders are familiar with the damage caused by this insect pest which is frequently found attacking the hardwood timber in the house. Floor and ceiling joists are the most common portions which suffer damage. The occupants of the house notice the piles of dust made by the boring larvae, and, after closer inspection, find small holes in those pieces of hardwood from which the dust is being extruded. These discoveries frequently cause considerable alarm owing to the belief that the borers, unless checked, will steadily destroy the timber framing of a house until the whole structure collapses upon the unfortunate occupants. Nothing could be more absurd, for such a happening has never been recorded, and there is no likelihood that in Australia it ever will. In fact, it is very rare indeed to find in any house a piece of timber damaged by this borer to such an extent that it must be replaced.

The powder-post borers live on starch which is present only in the sapwood of timbers, e.g., certain of the Australian hardwoods. The sapwood varies in width according to the different species, but is on the average no wider than 1 inch. Most of it is removed during the conversion of the log into boards, but strips and edgings of sap are frequently left on building timbers. The borers, which are common in all countries of the world where hardwood timbers are used, explore the fresh sawn timber and infest any pieces of suitable sapwood that are available. They do not attack the rest of the timber which never contains starch and is thus immune. The destruction of the sapwood strips and edges is of no importance as far as the strength of the timber is concerned. In the majority of cases one has to crawl beneath the floor or climb above the ceiling to find the damage, which in most cases can be regarded as negligible.

There are many houses in Australian cities in which borer-attacked timber has been in service for many years. The borers have disappeared after destroying the small amount of sapwood available in the structural timbers, and the present householders are either unaware of the presence of such timber or have wisely forgotten that the borer was ever present. The powder-post borer should not be regarded as a menace to houses, and the best thing to do if its presence is detected in rafters, joists, or roofing timber, is to forget it.

In cases of attack in furniture where the holes in the infested wood present an unsightly appearance, there are two courses open:—

(1) If the piece of timber is badly attacked, it is best to replace it by sound material free from sapwood.

(2) If the attack is detected in the early stages before much damage is done, the piece of timber can be treated by forcing a solution of para-dichlorbenzene in kerosene into the flight holes by means of a small syringe.

Full details of this method of treatment, which is cheap, simple and effective, have been given in Trade Circular No. 6, which is issued free of charge on application to the Chief, Divison of Forest Products, Yarra Bank-road, South Melbourne, S.C.4.

The Fruit and Vegetable Preservation Research Station, Campden, Gloucestershire, England.

This Station was established under the aegis of the Board of Agriculture and the University of Bristol, and it initiated active work in 1923 when two research workers were appointed. In 1926 a National Food Canning Council was appointed, and additional funds were provided for the Station by the Board of Agriculture and by certain tinplate manufacturers.

The problems first investigated were concerned mainly with the selection of suitable varieties of fruits and vegetables for canning, the protection of the cans by means of lacquering, the practical difficulties arising from corrosion of the tinplate by acids, and the detailed study of certain canning processes. The Station was able to render valuable aid to the industry which has expanded very rapidly. Contributions are now obtained from the industry based on the average number of hands employed in the canning and bottling sections of each individual firm's business. The Government grant, amounting to £4,500 per annum, is received through the Department of Scientific and Industrial Research. About £1,500 per annum is contributed by the industry. Small grants are received from South Africa (£75), which proposes to establish a canning research station attached to the Low Temperature Research Station at Cape Town, and from Malaya (£50), which has established a station at Johore. The Imperial Council of Agricultural Research of India is equipping a small experimental station in Baluchistan.

The experimental facilities at the Station include chemical, biochemical, physical, and bacteriological laboratories, constant temperature rooms, chilling and freezing rooms, and a room for the sampling of canned products. There is also a large experimental room fitted with machinery for the canning of fruits and vegetables. Adjoining the Station there are about 3 acres of land used for the growing of vegetable varieties for canning trials. The total number of the staff is fourteen.

Investigations in progress include those relating to heat resistant moulds, heat penetration in the processing of canned and bottled fruits, temperatures of sterilization, &c. The Station has taken an active part in the extension of the National Mark Scheme to include canned fruit and vegetables. The statutory standards are based on the results of work carried out at the Station, which also conducts the official examination of cans packed under the Mark.

The information service is regarded as one of the most important functions of the Station. In addition to information and advice given in person or by telephone, about 800 technical inquiries are received and answered annually by letter. The Station keeps in close contact with industry through a Technical Advisory Committee. About 200 inquiries relating to factory difficulties are also received annually, many of them requiring experimental work and visits by members of the staff to the factories concerned. The information and advisory service is restricted to contributing members and is free.

The Station has been instrumental in establishing a large and successful industry in the canning of vegetables in Great Britain.

Scientific Research in Holland—The Netherland Central Organization for Applied Research.

This organization was established by Act of Parliament in 1930. The central Council consists of sixteen members, two representatives each of eight Government Departments, one representative having scientific qualifications and the other being engaged in industry. Under this central Council there are four Committees for manufacturing, agriculture, health, and fisheries, respectively. These Committees consists of about twenty members each. For example, the Manufacturing Committee comprises two representatives each of the Institute of Engineers, the Chemical Society, and the Physics Departments of the Universities, three representatives of industry, three of labour, and one of Technical High Schools, while several other interests have the right to appoint one member each.

The Committees make recommendations to the Council as to researches to be undertaken, the estimated expenditure, and the institution or place at which the work is to be conducted. The Minister of any of the eight Departments concerned has the right to veto any proposal affecting his Department. The allocation of funds is made by the Council, subject to the approval of the Minister for Finance. The Government contributes to the cost of the work generally on a £1 for £1 basis, though there is no hard-and-fast rule to that effect. In some cases the whole cost is borne by the Government. The Government has not yet established any central research laboratories of its own, the work being carried out at Universities, High Schools, and special laboratories which have been provided mainly by the industries, themselves, e.g., rubber, leather, fibres, wool, ceramics, sugar beet, paint, &c.

The organization of the work has not yet proceeded very far. The only one of the four Committees which is actively at work is that relating to manufacturing.

Animal Husbandry—Visit of Dr. John Hammond, F.R.S., M.A., D.Sc., to Australia.

As a result of funds recently made available for the purpose by the Commonwealth Government, Dr. John Hammond, F.R.S., M.A., D.Sc., of the Animal Nutrition School, University of Cambridge, will shortly visit Australia. He will arrive in Sydney early in March, and after touring the various States will leave Fremantle early in May.

Dr. Hammond is an outstanding authority on animal production, and is familiar with conditions and problems in Great Britain, United States of America, Argentine, and Europe (including Russia). As a physiologist, he is an active worker in the fields of (i) animal nutrition in relation to the production of beef, mutton, and pork, (ii) the reproduction of domesticated animals, and (iii) breeding, particularly for milk production. He was instrumental in the establishment of a pig-recording scheme and a bull-recording scheme in Great Britain. For many years he has carefully analysed British market requirements in beef, bacon, mutton, and lamb.

Most of the matters on which he has become an authority are of the greatest importance in the field of animal production in Australia. The advantages of obtaining the advice of an expert who has specialized on the problem of animal production for the trade requirements of the British market will be obvious at once.

Negotiations for the visit were originally put in hand by the New Zealand authorities who then invited Australia to participate. Dr. Hammond will spend some weeks in New Zealand before coming on to Australia.

Whilst in Australia the Council will look after the visitor in co-operation with the various State Departments of Agriculture and other interested bodies. A Committee representative of the Council, the Standing Committee on Agriculture, the Department of Commerce, the Australian Dairy Produce Board, and the Australian Meat Board has been set up to assist in various ways, including the preparation of an itinerary.

Co-operation in Timber Grading.

At the present time, Mr. Simpson, Senior Inspector of the New South Wales Railways, is spending some time in the Division of Forest Products, studying its methods of timber grading. This close co-operation between an officer of a large Government timber-using department and the Division is most valuable, and Mr. Simpson's visit will doubtless prove mutually advantageous to the two organizations concerned.

Experiments on the Use of Timber in Structures.

Mainly because of improved methods of design, the use of timber for structural purposes has greatly increased overseas, particularly in Germany and the United States of America. There are indications that, in Australia also, timber will be increasingly used for such purposes, but before this can take place it will be necessary to solve some problems in design which, owing to the use of different timber species, are peculiar to this country.

Overseas, dry or partially dry softwoods are the rule for structural purposes, but, in Australia, slow-drying green hardwoods are almost invariably used. One important problem on which practically no information is available is the unsightly sagging of timber beams under long-continued loads. This sagging is particularly serious with green hardwood beams, and the Division of Forest Products has initiated a preliminary series of experiments to obtain some data that can be used in design. The number of variables to be investigated is very great, and it has been necessary at the present stage to limit the scope of the experiment, because of the high cost of the equipment required.

A number of mountain ash (*E. regnans*) beams, 4 in by 2 inch in cross section and of span varying from 6 feet to 20 feet, are being loaded with dead weights, so adjusted as to give unit stresses of from 2,000 to 7,000 lb. per square inch in the outside fibres. Various conditions of moisture content and exposure are being investigated, and readings of the deflection made at regular intervals.

Tests are also being carried out to investigate the feasibility of using models in the study of the problem. One inch by half inch specimens have been coated with red lacquer in order to reduce their rate of drying to that of the 4 inch by 2 inch specimens, and the model beams will be loaded under similar conditions to the larger beams.

If it proves possible to use models in such an investigation, the problem will be considerably simplified, as a much larger number of tests can be made without prohibitive expense.

Review.

"A Textbook of Plant Virus Diseases," by Kenneth Smith, D.Sc. (Manch.), Ph.D. (Camb.).

(X + 615 pages, 101 illustrations, price 21s. Published in 1937 by Messrs. J. and A. Churchill Ltd., of 104 Gloucester-place, Portman Square, London, W.1.)

Just as something over half a century ago diseases caused by bacteria formed a new and enthralling field for investigation, so during the past 25 years virus diseases of plants have attracted increasing attention. Many workers have brought about the accumulation of masses of data on symptoms, host ranges, and insect vectors. It is reasonably certain that the host ranges have actually enlarged during the period and that new strains of viruses have been developed.

Such a mass of data scattered through a wide literature requires to be brought together and classified, not only for the use of the beginning student in this field but also for the specialist. This, Dr. Kenneth Smith has done in a very thorough way in his Textbook of Plant Virus Diseases. It is arranged according to host plants which are placed in families according to Hutchinson's system of classification (which begins with the Ranunculaceae), and the viruses are numbered by hosts. Thus the first virus treated is Delphinium Virus 1, the last is Oryza Virus 2, and those of Nicotiana and Solanum are to be found in Chapters IV., V., and VI. Each disease is discussed as follows:—The virus and its transmission, differential hosts, diseases caused by the virus, geographical distribution, and control where known. Nearly 100 pages are devoted to an account of the vectors of plant viruses, and each vector is described and an account of its life history and habits is given. A very useful appendix for preliminary diagnosis (pp. 560-597) tabulates the most characteristic symptoms of the various virus diseases on the more important plants.

The book is excellently illustrated. The print is good, but in the reviewer's opinion some of the captions could well be in different type.

It is a book which will be welcomed by all workers in, and students of, virus diseases of plants.

B. T. D.

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publications of the Council have been issued:—

Bulletin No. 112.—"Studies in Fertility of Sheep," by R. B. Kelley, D.V.Sc.

This publication is the first of a series which will deal with the general question of fertility in sheep. In some Australian localities, and particularly in the semi-arid regions, the fertility of Merino sheep can hardly be regarded as very satisfactory. As a first step, attention has been concentrated on the study of the physiology of sheep, for without further knowledge of the normal reproductive functions of the animal it is not possible to solve problems associated with low fertility and which may from time to time worry the stud-breeder and the flock-master. In the present publication the results of five studies that have been made into various phases of reproduction in sheep are given. Highly, normally, and lowly fertile types were secured, and their behaviour contrasted under conditions as nearly natural as possible.

Bulletin No. 113.—"Studies on Coast Disease of Sheep in South Australia," by H. R. Marston, R. G. Thomas, B.Sc., D. Murnane, B.V.Sc., E. W. Lines, B.Sc., I. W. McDonald, B.Sc., B.V.Sc., H. O, Moore, B.Sc., and L. B. Bull, D.V.Sc.

The study of malnutrition that occurs in sheep in many parts of the coastal districts of South Australia was commenced some years ago. The investigation has now reached a stage when more or less definite conclusions appear to be possible. Such are published in the present Bulletin, which concerns work centred at the Nutrition Laboratory, Adelaide, of the Division of Animal Health and Nutrition. Different aspects of the investigations have been reported in the Bulletin by the different investigators concerned. The similarities between coast disease and enzootic marasmus of Western Australia, bush sickness of New Zealand, pining disease of Scotland, nakuruitus of Kenya, and salt sickness of Florida, are discussed. Ataxia in lambs is also described; it occurs in association with coast disease as well as occasionally on country where typical coast disease is unknown. It is tentatively suggested that the primary cause of coast disease is a dual deficiency of cobalt and copper in the pastures of affected areas.

Bulletin No. 114.—"The Wood Structure of some Australian Rutaceae with Methods for their Identification," by H. E. Dadswell, M.Sc., and Audrey M. Eckersley, M.Sc.

The previous work of the Council's Division of Forests Products as regards wood structure was directed toward the establishment of useful keys for the identification of the more important commercial species of Australian timbers, both eucalypt and non-eucalypt. The results of this preliminary survey have been set out in Bulletins 67, 78, and 90. With this background, the present Bulletin deals with the timbers of the family Rutaceae. The results obtained in the examination of the wood structure of 23 different Australian species of the family have been set out, particular attention being paid to the species

of the genus *Flindersia*, since valuable commercial timber is derived from all of them. Photomicrographs showing the finer details of structure and low power (10X) photographs of the end sections of the various woods have been included.

Pamphlet No. 74.—"Studies on the Chemotropic Behaviour of Sheep Blowflies," by Martin R. Freney, B.Sc.

The work described in this publication represents a portion of a comprehensive investigation of the sheep blowfly problem which is being carried out by the Council's team of investigators. It discusses studies on the chemotropic responses of sheep blowflies to various baits and chemicals. The objects of the investigations were to discover exactly what substance attract *Lucilia cuprina* to feed and to oviposit, to discover why this fly is attracted so strongly to susceptible sheep, to devise baits to catch large numbers of *L. cuprina*, and to discover substances which render carrion or live sheep unattractive to *L. cuprina*.

Pamphlet No. 75.—"Collapse and its Removal: Some Recent Investigations with *Eucalyptus regnans*." (Division of Forest Products—Technical Paper No. 24), by W. L. Greenhill, M.E., Dip. Sc.

A theoretical discussion of the causes of collapse in timber and its removal by reconditioning is given. Results of preliminary experimental investigations made into the effect of various kiln-drying schedules and certain preliminary heat treatment of green mallet on the occurrence of collapse and its removal are outlined. The results of tests made to determine the effect of the moisture content of collapsed timber and of the temperature of reconditioning and its response to treatment are also described.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 115.—"A Soil Survey of Part of the Denmark Estate of Western Australia," by J. S. Hosking, M.Sc., A.I.C., and G. H. Burvill, B.Sc. (Agric.).

Bulletin No. ?.—"A Soil Survey of the Horticultural Soils in the Murrumbidgee Irrigation Areas of New South Wales," by J. K. Taylor, B.A., M.Sc., and P. D. Hooper.

Bulletin No. ?.—"The Relation of Phosphate to the Development of Seeded Pasture on a Podsolized Sand," by H. C. Trumble, M.Agr.Sc., D.Sc., and C. M. Donald, B.Sc.Agr.

Pamphlet No. ?.—"Grading Studies in Ash Eucalypts," by R. F. Turnbull, B.E., A. J. Thomas, Dip.For., I.F.A., and F. E. Hutchinson, B.Sc.F., B.For.Sc.

H. J. Green, Government Printer, Melbourne.

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